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FIG. I. A FOREST IN THE CARBONIFEROUS PERIOD

At the time when the coal seams were laid down there was no cold winter, and the surface of the whole of our planet was a warm swamp teeming with vegetable life, growing in the mud, floating in the water, and hanging in the air. Reptiles and insects abounded, but land animals and trees had not yet appeared.

SECRETS OF THE EARTH

By

STERLING CRAIG M.A. LL.B.

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PREFACE

GEOGRAPHY cannot be understood without some knowledge of the structure of the earth underlying its surface, and of the explanation which geology gives of the forces which have been, and are, at work in shaping the world as we know it.

The workers in our manufacturing towns are dealing every day with the products of the mines, and should take some interest in the work of the miners, on whose labour they depend; while agricultural workers would find life more interesting if they knew something of the nature and history and capabilities of the different soils they are cultivating.

To the lover of nature geology supplies the key which unlocks the hidden secrets of the countryside and makes every landscape, not only a picture, but a history reaching back millions of years.

Geological text-books, however, are often forbidding to the lay reader because of the number of technical terms employed and the time needed to assimilate them; this little book aims, rather, to explain geotechnic processes in simple language, and to provide a broad foundation of scientific principles, on which the young student may build a more detailed knowledge of the subject.

Geology is essentially an out-of-doors study, to be

pursued in quarries, on the hills, and by the rivers, and it has an intimate connexion with biology, botany, and natural history, which I have tried to show.

When this introductory book has been mastered the reader should be able to tackle the Geological Survey memoir and map of his own district—obtainable through any post-office—and to begin accurate and interesting outdoor work. He should read the whole book first, to get a general idea of the subject, and then study the chapters individually. This is not a text-book, and I have dealt at greatest length with the ideas which experience of excursions has shown me are the most difficult for beginners to grasp. Many of the chapters could be made the basis for nature-study lessons for younger pupils.

STERLING CRAIG

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CHAPTER I

THE VERY BEGINNING OF A LEAD PENCIL

HAVE you ever thought of asking the geological history of the fire we are now warming our toes at?

We see an iron grate, polished with black lead, coals burning in the grate, and a brick of fireclay at the back of the fire to prevent it burning away the iron. What can the geologist tell us about the history of these substances?

The black lead that the grate is polished with is not lead at all. It is not even a metal like iron or tin, but it is really a form of coal which has been so changed by the action of intense heat that it will not burn. Indeed, it is used for making crucibles for melting other things in, and can be made to resist heats that would melt even fireclay bricks.

Have you ever thought that this black lead is a vegetable product, and is as much the remains of a living plant as the wood of the pencil? Shall we try to begin at the very beginning of a lead pencil? The plumbago, or graphite, which is the proper name for the black stuff you write with, and use for polishing grates and kettles, and put into the working parts of your bicycle to make it run smoothly, was originally a gas which chemists call carbon dioxide. It is formed by combining two parts of oxygen with one of carbon.

We are all busy manufacturing this gas in our bodies,

and breathing it out into the air of the room. The fire in the grate there is turning the coal into this same gas, and sending it up the chimney. Very early in the history of the world there was this carbónic acid gas. It probably came out of the sun along with the rest of the material that the earth was made of.

Thousands and thousands of years after the stuff that the earth was made of came out of the sun, and had been flying through space round and round the sun, life first appeared on the earth.

You *know* what life is, but you cannot *tell* me what it is. Thousands of the cleverest men have been trying for over a hundred years to find out how life first came into this world; but they have not been able to tell us.

All that even the cleverest men can say is that plant life is a power which, in the presence of moisture and under the influence of sunlight, can take carbonic acid gas and water out of the air, break them up into carbon and oxygen and hydrogen, and then make from the particles of carbon and hydrogen a new substance which is alive. Everything which is alive begins, grows, and dies. Scientists can tell us a great deal about *how* it begins, grows, and dies, but no one has ever told us *why*.

We are all so accustomed to seeing plants and trees growing in the ground that we think that all the food for the plant comes from the ground. As a matter of fact, however, only one-fiftieth part of the substance of a plant consists of mineral matter taken from the ground; the other forty-nine-fiftieths of the plant consist of carbon, nitrogen, and water taken from the air. The roots

of a plant need air as well as the leaves, and a land plant will die from drowning if the ground is so soaked with water that its roots cannot get air.

The earliest form of plant life was probably some kind of one-celled plant like yeast growing in shallow water; but scientists have not yet determined whether we should call it a plant or a colony of small animals living together. When we get down to the very lowest forms of life it is difficult to say whether they are plants or animals. We shall be going far enough back if we begin with the yellowish-green spots, called lichens, which we sometimes see on rocks that have been long exposed to the sun and rain. They are among the simplest forms of plant life. Lichens grow very slowly, and even though you look at them through a powerful magnifying-glass, you would hardly see anything but a few specks of colour. Every plant that we know has roots and leaves, but these lichens have neither.

FIG. 2. STAGES IN DEVELOPMENT AND MULTIPLICATION OF CELLS

The lowest and simplest living things are small specks of jelly which we call cells. They have the power of taking in food from the air. The cell, which is originally round, gradually becomes egg-shaped, and then thickens at each end till it is like a dumbbell. Then this dumbbell breaks across the handle, and each end of the dumbbell becomes a separate cell and begins

to grow, and then becomes egg-shaped, and then dumbbell-shaped, and then breaks across the handle, and so multiplies itself.

A lichen is really a partnership or colony of separate cells living and working together. It is an organized community, and is in some ways pretty far up in the scale of life; but we need not go into that now.

At the time when the coal was formed the world was a very different place from what it is to-day. There was a great deal more of carbonic acid gas in the air than there is now. Carbonic acid gas, although it feeds plants, poisons all the other living things. If I were to go round this room and shut the door and windows, and seal up all the cracks round the window-sashes, and block up the chimney, so that no air could come in or out, we should soon begin to feel very sleepy. Then we should all have headaches, and possibly fall into a sleep from which we should never awake, because we should be poisoned by the gas which we are all breathing forth out of our bodies.

In the Carboniferous Period, when the coal was made, the earth was one great warm, steaming greenhouse. We now find the fossil [1] remains of tropical vegetation all over the world, even at the North and South Poles. It was the age of perpetual heat, mist, and fog. The whole land was soaking with water. Steam was rising up into the air and being condensed into clouds, and coming down again in the form of rain. Wide areas of land were covered over by shallow lakes and swamps

[1] Remains of animal or vegetable life which have been preserved in the earth and have become like stone are called 'fossils.'

connected by narrow channels. The action of winds and tides and the rotation of the earth kept warm water always circulating over the surface of the globe, and—like the hot pipes below the flags of the greenhouse—continually giving out moist heat. The clouds which surrounded the whole world, like a great pile of blankets, twenty miles high, kept the heat from escaping into space, and at the same time stored up all the heat that came from the sun.

If you went into a hot greenhouse you would soon become tired, and if you were imprisoned in such a place you would get weak and ill and probably die, because hot, moist greenhouse conditions are not suited to healthy animal life. Fishes and reptiles enjoy them, however, and they developed enormously during the Carboniferous Period. The highest forms of animal life then existing on the earth were gigantic lizards and enormous crocodiles. These had little brains, but were provided with gills like fishes, as well as lungs, so that they could breathe in both air and water. Insects flew about the tops of the trees, but the air near the ground was so full of moist vapours and the smells of decaying vegetation that animals breathing air alone could not have lived there, even had they existed.

You know that in swampy places plants grow very quickly, and are all soft, juicy, and flabby. You might almost say they are just so much water coloured green and made to stand upright. Nowadays the winter comes every year and kills off all these soft, flabby plants, but in the Carboniferous Period there was no winter, and all the plants grew big and fat, and died

very quickly of over-eating. In this way huge masses of vegetable matter soon covered the whole of the land.

Ferns grew into trees fifty feet high, gigantic mosses or lycopods sprawled over the swamps, with stems as thick as your body and hundreds of yards long, and horse-tails grew so big that one of them would have filled an ordinary class-room and grown through the roof till it was three or four times as high as the school.

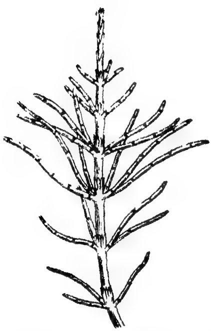


FIG. 3. HORSE-TAIL

The next time you see a horse-tail pull it up and have a good look at it. Why has it no leaves, or flowers, or seeds? How does it live without them? It is a real old conservative, and has no use for such new-fangled modern inventions as leaves and flowers. Its ancestors did without them forty million years ago, and it is doing without them to this day.

It is the oldest, simplest, and loneliest living thing in the whole world. You will find it in every country from the equator to the poles. Away far back in very old rocks we find the fossil remains of horse-tails. Through the long succeeding geological ages it contrived to live, and if you leave any bit of your garden unplanted to-day the horse-tail is one of the first weeds that will come and establish itself there.

The horse-tail is also the loneliest living thing in the whole world, because it has no relations. Every other plant and animal and bird and fish has cousins that are

very like it and are only just distinguished from it by one or two points of difference.

The *Equi-se-tace-æ* (to give them their proper botanical name, because they are very, very select) are not only a separate family, but a separate natural order, all by themselves. Their way of producing descendants is different from that of almost every other plant in the world. Each horse-tail is the grandchild and not the child of the horse-tail that preceded it. Its immediate parents were separate microscopic plants that perished as soon as they gave it life, and were not in the least like horse-tails. Horse-tails resemble animals in having a jointed backbone, and they resemble shellfish in having a hard outside skin, which contains a large amount of the mineral silica. If you burn a dry horse-tail in a gas flame you will get tiny beads of glass. Glass is principally melted silica, and is made by heating sand along with a little lime. This silica makes them very useful in polishing marble, ivory, cabinet-work, etc., and for this purpose large quantities are imported from Holland under the name of Dutch rushes.

But you may find it difficult to understand how tropical vegetation could grow at the North Pole, and the whole world be like a steaming hothouse all the year round, as it was in the Carboniferous Period. Where was the heat to come from? If it came up out of the ground you would imagine that it must burn up all the roots of the plants.

The answer would seem to be that the world hothouse of the Carboniferous Period was heated much in the same way that our hothouses are heated to-day, by

currents of hot water. The hot-water currents were not enclosed in iron pipes, because the world had a mechanism of its own for making the water circulate, but the principles involved were the same.

The fact that there was no cover over the hot-water currents was rather an advantage to the vegetation, as the escaping steam supplied abundant quantities of moisture, and it made no difference to the hot-water system that the water-pipe was five miles across instead of five inches—or even fifty miles. At the time the coal beds were made there were no great land continents and no oceans. The whole world was dimpled over with large islands and shallow seas. The crust of the earth was very much thinner, and like the wrinkled, wobbly skin of a half-filled balloon. The warm currents of water coursed freely and regularly from the equator up round the poles and back again.

It is difficult to imagine Greenland enjoying the luxury of a hot climate, but fossil fig-trees and palms, and many other tropical plants, have been discovered in the rocks there, so that we know these trees must have flourished in Greenland at one time. There is also ample evidence to prove that the country round the South Pole once supported a tropical vegetation.

I cannot explain how such a great change has been brought about, but if you think for a little about some of the effects which the warm currents in the ocean and in the air produce at the present day you will be bound to admit that even greater changes in the climate of any part of the world are not impossible.

During the Carboniferous Period the world was com-

paratively formless. The surface of the earth was continually sinking in some places and rising in others. A land on which some great forest, thousands of miles across, was growing would gradually sink lower and lower, until the rivers all round it turned and flowed into it, instead of into the sea, because it would be lower than the old sea-bottom; and perhaps the sea itself would flow up along some sunken river valley, and cover a whole forest.

This would kill all the trees and plants, and they would sink down and form a tangled mass at the bottom of the water.

The rain in those days was probably a hundred times heavier than it is now, coming down in thunder-showers every half-hour, and washing away the sides of the mountains very quickly. The rivers would be thick with mud, and at times flow like treacle, bringing down sand and gravel enough to fill up the great lake in which the old forest of marsh-plants had been drowned. Floating masses of vegetation often became water-logged and sank to the bottom.

Now, as the whole world was a steaming, stifling hothouse, all kinds of plants grew very quickly. Long before the lake had been filled up giant horse-tails, mosses, and jungle-plants would creep in from its shores, and every variety of water-weed would be growing on the surface. Then, as the lake became shallower and shallower, scale-trees and monkey-puzzle trees and tropical ferns would spring up out of the marsh, and their dead stalks and leaves would help to fill up the lake, until a new forest had grown up on top of the old

one. Then this land would sink down into the earth again, and make a new hollow, which would fill with water. This would kill the trees, and they would fall to the bottom, and so repeat the process.

There are often ten or twenty different seams of coal lying on top of one another, each separated by beds of sandstone, or fireclay and blaes,[1] or shale, or limestone and ironstone. This shows that that part of the earth's surface had first sunk, then remained steady, and then had sunk again; this process being continued for thousands and thousands of years.

Coal is bottled sunshine. The sunbeams gave the growing plants their strength and energy to break up the little particles of carbonic acid gas, digest the carbon, and build it into their own bodies, setting the oxygen free. This store of carbon supplies our coal to-day, and when we put the coal on the fire we are reversing the work done for us by the plant-cells.

When coal burns its carbon is united again with oxygen, and forms carbonic acid gas that flies up the chimney, while some of the heat comes out into the room and warms us. As we sit now, warming ourselves by the fire, we are really enjoying the sunshine of millions of years ago, preserved for us by luxuriant tropical forests that lived and died in that far-away past.

If during the Carboniferous Period the whole world was a big greenhouse, so filled with growing plants that you could not walk through it anywhere without crushing them down, and squeezing your way in between

[1] Clay baked into stone.

tree-trunks, you might ask why it is that we do not find coal everywhere.

The answer is that while there was plenty of vegetation that might have become coal, there was no bottle to contain it. While the plant is growing it is taking carbon out of the air and building it up into itself. When the plant dies thousands and thousands of 'breakers-up' cluster all round it, and they break up all its particles into carbonic acid gas. All the substance of the plant that came out of the air goes back into the air, and the mineral salts which the roots took out of the ground are left lying on the ground. The same thing is done very much more quickly when we set fire to a pile of sticks. This is why we find that in some places where we know forests have been growing for over a thousand years there are only a few inches of vegetable matter lying on the ground.

The luxuriant forests of the Carboniferous Period have been preserved for us in much the same way as we preserve fruit by bottling it. You have seen cherries placed in bottles, and water poured in to fill up the spaces between the cherries. Then the bottles of cherries are put into a large pan and heated till the water boils, in order to drive out all the air. A special lid with an indiarubber lining is screwed down over each bottle, so as to prevent the air from getting in again. In this way the 'breakers-up' are prevented from attacking the cherries, and they will keep good, and may be eaten two or three years after being bottled.

Our coal has been preserved for us in the same way as the cherries, or the tinned meats which we get from

America and Australia, though the 'tins' were a hundred miles, and sometimes a thousand miles, in diameter.

If a tree falls on the ground and dies nearly all its substance is broken up into gases and escapes into the air; but if it falls into water the water preserves it, and it may last for hundreds of years. The first preservative agency which made our coal was the water into which the tree-trunks fell. We always find in a coal-field that above the coal there is a layer of some kind of clay or mud rock. It is not always directly on top of the coal; there may be one or two layers of sandstone between. This layer of clay-stuff, which is called shale or blaes, acts in the same way as the lid of the jar in which the cherries were preserved. It seals up the moist mixture of fallen trees and mud, and prevents the gases formed by the decomposition of vegetable matter from escaping. By thus bottling the whole thing down the clay keeps the fallen trees from decomposing, until by the action of the weight of other new rocks laid down by the rivers on top of it, and the heat coming up from the centre of the earth, the tree-trunks are squeezed and baked and boiled into coal.

It is only when all these agencies combine that we get coal. First of all we have the vegetation, consisting of marsh-plants, tree-ferns, tall trees, and general tropical jungle. Then we have the water, which kills the trees and plants, and covers and preserves them from further decomposition until the beds of mud and sand brought down by the rivers have been laid down on top of them. Then the layers of clay and shale cover all, and finally the jungle trees become coal.

If the gases formed by the rotting of this vegetation had been allowed to escape into the air it would have all rotted away millions of years ago, and we should have had no coal. It is these gases imprisoned in the ground for millions of years that poison the miners and cause explosions in the pits to-day. Currents of fresh air have to be constantly forced down into the mines to drive away these gases, which exude from the rocks when the coal-seams are opened up.

Very frequently we find the fossil roots of the coal plants and trees growing in a layer of fireclay or sandstone; then we have a seam of coal formed from the remains of this vegetation resting directly on the fossil stumps of the old trees. Above these we may find a bed of sandstone, then another of shale or blaes, and after this, in a higher bed of clay, the fossil roots of the trees of another generation of forests, with a layer of coal on top of them, and so on till in some places as many as fifty seams of coal have been found lying above one another and all sandwiched in between sheets of sandstone and claystones.

You must remember that while by far the greatest part of our coal is formed of the remains of marsh-plants, and not of trees at all, still, during the Carboniferous Period there were a number of trees growing on the uplands which surrounded the swamps. Occasionally one of these trees would be swept down by a river into the swamp, along with the coal-forming plants, and so preserved as a fossil tree.

You will be wondering when I am to come back to the lead pencil. Well, plumbago or black lead is a very

much rarer mineral than coal, and is found where the coal has been baked by an intrusive mass of molten rock squeezed in above or below the seams of coal. There are several coal-fields where ordinary coal is found over a large area, but when we come across a solid plug of lava which has cooled, and filled up the pipe through which it poured, we find that the coal nearest the plug has all been burned to coke. The coal next the coke has been melted by the intense heat and changed from coal into plumbago. The coal lying near it again has in some places been changed by the heat of the lava into anthracite, or steam-coal, which is so much used by our warships. It burns without any smoke, because the gases in ordinary coal, which give rise to smoke, were all burnt out of the steam-coal by the lava, which baked it underground thousands of years ago.

The rocks in which plumbago or black lead is usually found are full of fossil 'sea-pens' or graptolites, showing that they are far older than the coal measures, as we call the rocks the coal is found in. It is, however, pretty certain that most of the black lead we know of once formed part of a growing plant.

CHAPTER II

A SANDSTONE QUARRY AND FOSSILS

THE nearest sandstone quarry, and not a class-room, is the best place in which to begin the study of geology. If there is no sandstone in your district a limestone or a road-metal quarry will do. Failing this, a brickfield, a railway-cutting, a river-bank, or an excavation for a big drain or foundation will serve. Get into contact with the actual rocks at once, and try to find out what they are, and in what direction they are sloping. Geology is essentially an outdoor study, and the great difficulty of treating it adequately in a text-book lies in the fact that it consists in a minute examination of local geography, which differs in every district, so that every separate parish would require a book of its own.

This little reader gives you all the general information you want before beginning practical work. The whole country has been carefully examined by the Geological Survey. This department has published separate short accounts of the geology of each district, which are cheap and easy to understand.

Go to the nearest post-office and order a large-scale geological map of your own district and the part of the Survey memoir which deals with it. These will be posted to you for a few shillings, and with their aid you will see exactly where you are living geologically, and you will be in a position to begin accurate work at once.

Sandstone gets its other name of 'freestone' from the fact that it is found in great broad, continuous sheets or layers which come away freely from one another and break across in straight lines, so that it can be readily cut into oblong blocks of convenient size for use in building.

The layers of rock in a sandstone quarry are like the pages of an immense book. At first you might think it was all of one substance, but if you look carefully you can make out the seams. The layers of rock vary in thickness, from less than an inch to five or ten feet, but a great many of them are from six inches to two feet thick.

If you try to split a piece of wood, and drive your axe down in the direction in which the tree has grown, that is, in a line with the grain, it splits quite easily. If, on the contrary, you try to cut or break it across the grain it will not split; you have to cut through every separate fibre. Sandstone rocks can be split in the same way, and it is this cleavage which makes them easy to cut.

Although the layers of sandstone were originally laid down quite flat on the bottom of the sea, the great wave-like movement of the earth's crust which has lifted them up has generally left them lying not quite flat, but 'rising' up or 'dipping' down in one direction or another. The angle at which the layers of rock slope downward from the horizontal is called the angle of their dip, and the geographical direction in which the rocks are running down into the earth is the direction of their dip. Always try to find out the angle

FIG. 4. THE TWINS, BLUFF CITY, UTAH

Observe how the 'jointing' or vertical cracking of the rocks has allowed the weather to decay away the whole cliff, till only these two pillars remain. Their height, from the bottom of the cliff, is 275 feet.

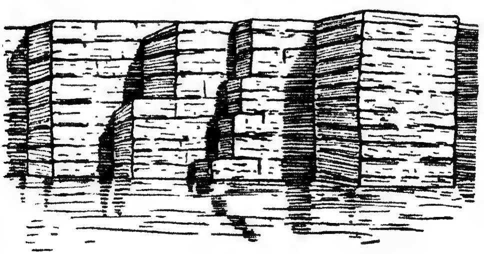


FIG. 5. JOINTED SANDSTONE

and the direction of the dip of the strata, as this is the foundation of all geology.

If all the layers of rock had lain quite flat we should have been always walking about on the top layers, and we should have known nothing about the rocks underneath us other than the limited amount revealed by excavations. There would probably have been no 'Coal Age,' or 'Steel Age,' or 'Oil Age,' no mining, and no science of geology, or evolution theory. The earth's history would have remained sealed up under its outside coat of rocks.

FIG. 6. SEAMS OF COAL EXPOSED IN SANDSTONE CLIFFS WHICH HAVE BEEN PUSHED UP OUT OF THEIR PLACES TILL THEY ARE NEARLY PERPENDICULAR

Sandstone rock is formed out of grains of sand which have been washed down by a river at some time. This rock was probably formed at the bottom of a great lake. Every time the rivers were flooded by heavy rains they brought down great quantities of sand with them. When the water of the river reached the lake it could

flow no farther, so it stopped, and the grains of sand dropped out of it on to the floor of the lake, and lay there piled up, one on top of the other.

In some places these sandstone rocks are several hundred feet thick. Water was constantly circulating up and down among the sand grains, and leaving behind it small quantities of lime, which it had dissolved out of broken shells or the bones of animals, which had also been brought down by the rivers. These small quantities of lime and other minerals cemented the sand grains together. The tremendous weight of these layers of sand and mud, piled one above the other, crushed the sand so close together that it became solid rock as you now see it. After lying under the water for many thousands of years the floor of this great lake has been raised up again and become dry land.

Fold the diagram on p. 31 backward along the line A to B, and stand it with its edge perpendicular to the page below it. Turn the edge of the book toward you, and you have something like a model of a set of mineral seams—shale, limestone, fireclay, ironstone, sandstone, and coal—dipping south-east at an angle of 15° to the horizon. (You are now dealing with space of three dimensions, which cannot be represented on a flat surface of two dimensions, and it will pay you to get an empty cardboard box, and work out the positions of these mineral seams on all the six sides of it.)

The breadths of the outcrops of the seams, where they come to the surface of the ground, represented by the left-hand side of the page, are greater than their heights in the perpendicular section on the right-hand

side, because, owing to the angle of 15° at which they are dipping, the horizontal page cuts them in a slanting direction. If the seams were lying flat above one another like the pages of this book, then each seam would cover a whole page. Or if the seams were standing straight up on their edges, or, as miners say, were dipping down perpendicularly into the earth, then their outcrops at the surface would be the exact widths of the seams—that is, their outcrops would be their edges.

'Dip' signifies two things: (1) the geographical direction, as determined by the compass, in which the seam is running down into the earth, which may be north, south, east, or west, and (2) the angle which the seam makes with the horizontal plane. The 'strike' of a seam is a horizontal line drawn at right angles to the geographical direction of its dip.

The place where the mineral seams reach the surface, or would crop out from it if they had not been cut off flat by the surface, is called their 'outcrop.' If the surface of the ground were perfectly horizontal, as in the diagram, then the strike and the outcrop would coincide. This, however, seldom happens.

Hold a book sloping downward with the front edges on the table. The geographical direction in which it is pointing is the direction of its dip, and the smallest angle between it and the table is the angle of its dip. The back of the book represents its strike.

In the diagram the dip is south-east and the strike is north-east. The geographical direction of the strike is always at right angles to the geographical direction of the dip.

Had the seams in the diagram been dipping directly north and south—that is, right down the page—then

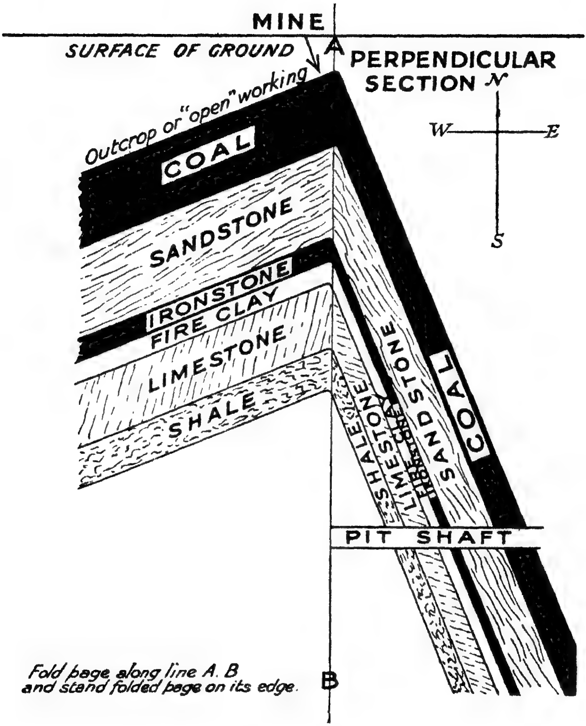


FIG. 7

the strike would have been east and west, right across the page. If a seam dips to the west, then its strike is north and south, and so on. In the district indicated by the diagram the coal would be first dug out as an

open working, till the miners came to the rock underneath it. Then they would follow the coal by driving mines under the sandstone, and finally they would sink a pit down through the overlying rocks till they came to the coal and draw it up in buckets. When you have found out exactly the direction in which a set of rocks is running across the country, and the angle at which the beds are sloping down into the ground, you can calculate exactly where that set of rocks is lying inside the earth. If you are a coal-miner you can tell where the seam of coal is, and how far down you will need to sink your shaft to get to that coal. If you are a geologist you write down carefully on your field-map the places where that seam of rocks comes to the surface, and the angle and direction of its dip, and you calculate where that set of rocks ought to be in the next river valley. Then you go and look for them there. If you cannot find them you know either that your calculations are wrong, or that that seam of rocks has been bent in some other direction underneath the ground. It is by making hundreds of observations as to where the sets of rocks come to the surface, and the directions and angles at which they run down into the ground, that the geologists have been able to prove that all the mountains have been made by foldings of the earth's crust as described in Chapter XI.

Fossil trees that have been found embedded in the rock may often be seen in museums. If you have an opportunity, go and have a look at one. You can see at once that it is a tree. Here the bark has been left on, and there large pieces have been stripped off. At this

place, where the trunk has been cut across, you can see the rings in the tree.

It is quite possible, by studying the fossil carefully, to tell what kind of tree it was, although, of course, there is not a particle of actual wood left. It is all mineralized through and through so as to make it almost the same as the rest of the quarry rock. Every particle of the original vegetable, as it decayed away, has been replaced atom by atom by mineral matter. This replacement of the vegetable particles by mineral particles has been so exceedingly accurate that microscopic specimens of the fossil tree can be studied, and its whole history ascertained. From examining two or three fossil trees we can get an idea of the climate at the time when they lived and the kind of foods available, and therefore the animals that could have lived there then.

This tree was growing millions of years ago by the side of a river. It died and fell into the stream, and was carried down, along with all the mud and stones, into the bottom of a lake, where it was buried in the sand and changed into stone.

Some people expect to find fossils every time they go into a quarry. But if you will think for a moment you will see this is very unreasonable. How often do you find the skeletons of birds or small animals while you are walking in the fields or woods? Yet thousands of them die every day. If all the country were covered up by three feet of loose sand, even, you might have to dig over acres and acres before you found a single skeleton. You have no more right to expect to find fossils in every yard of rock than to find animal skeletons

in every yard of country. Many quarry-men and miners are interested in geology and lay aside any fossils they find so that visitors may examine them, and you should look into a quarry every time you come across one, and if you find any stone which interests you take it home and at once label it with the name of the place where you found it.

You have often seen the ripple-marks due to currents left upon the sand, and if I can show you these marks in the solid sandstone that will prove that this has once been a shore. Supposing here before us is a slab of rock showing ripple-markings.

One sunny day, thousands and thousands of years ago, the wind rippled the waters of the incoming tide, when the sandstone rock on which we are standing was loose sand on the seashore. When the tide went out for the last time the marks of the ripples were left on the sand, just as we see them here in this solid rock to-day.

You remember how Robinson Crusoe found the footprints on the shore, and knew by them that some man with bare feet must have walked across that place since the tide went out, and that this led him to look out for other signs of human visitors to his island?

In the same way footprints in the rock, which could not have been caused by any bird or animal now living on the earth, have led geologists to look for other signs and remains of the animal that must have made the footprints. Little by little so much evidence has been collected that, although the last of these extinct animals must have died out long before there was any man living on the earth, we can tell how big they were, what

they looked like, what they lived on, and, in fact, all the important things about them.

We may, for example, see a trail of markings in the rock which were formed by the footprints of a large bird. From these footprints we can tell what size of a bird it was, and what were its habits, because every animal's body is adapted to the way in which the animal lives.

By examining a bird's foot we know whether it is in the habit of flying and resting on the branches of trees; or walking on the ground, and scraping for its food, living like a hen; or swimming about like a duck.

The dead bodies of animals which lived in those bygone ages would also be washed down along with the mud of the river, and though all the soft parts of their bodies would be dissolved without leaving any trace the bones would be turned into fossils, and in this way we can tell what kind of animals lived on the earth hundreds of thousands of years before man was created.

During the last century we learned a great deal about the people who lived long ago by examining the remains which they have left behind them. Two towns, called Pompeii and Herculaneum, which lay at the foot of Mount Vesuvius, were one day buried underneath a great shower of volcanic ashes from that mountain. The place where these towns were was well known. Many years ago a company of learned men, who were interested in studying the life of the old Romans, determined to dig away all the ashes, and there they found the houses, the streets, and the bodies of the people, who had been overtaken while going about their daily work

over eighteen hundred years ago. They found the body of a Roman soldier clad in full armour, with helmet and spear, as he stood on duty. Remaining nobly at his post, he had been buried amidst the falling showers of dust.

Many articles of furniture, pots and pans, and everything else used in the daily life of the Romans, were also preserved in the ruins of these buried cities, so that we know almost all that can be known about these people. We have obtained a more intimate knowledge of Roman life from these excavations than from all their histories and books.

Excavations in Egypt have laid bare old cities, temples, and tombs which had been covered by the drifting sands of the deserts, and our museums have now a great many relics of these ancient times. The fossils in the rocks tell us, much in the same way, the history of the world.

The town of Pompeii preserved under its shower of ashes, and the old temples of Egypt sealed up in their sands, are just very, very new fossils. The old fossils tell us about the animals that lived on the earth millions of years ago in the same way that the excavations of these buried cities tell us of the life of their inhabitants two thousand years ago.

The most interesting, because the newest, fossil in the world is in the museum at Leningrad. It is a mammoth, or woolly-haired elephant, which was found in Siberia. This animal has long been extinct. No one knows how many thousands of years it is since this one lost its life, but the mass of ice-cold mud into which it

had fallen had afterward frozen over its dead body and preserved it so perfectly that Dr Hertz found fragments of its last dinner still sticking between its teeth and the well-preserved remains of a recent meal in its stomach. The flesh of this mammoth was so fresh that after the mud had been removed and the sun had had time to thaw it the native dogs greedily ate it. If the natives had not dug away the frozen mud which covered it the mammoth might have been preserved in this natural cold-storage vault for many thousands of years to come. Scientists could not account for the body of an elephant being found so very far north. Some supposed that it had been carried over a thousand miles by a great river; others said this was quite impossible, and denied that it was an elephant. It was very carefully examined. Pine needles were found sticking between its teeth, which showed that it had been feeding on the young branches of fir-trees, and thick woolly hair coated its body. This proved not only that the elephant had lived in the very place where it was found, but that the climate had become colder and colder so gradually that succeeding generations of elephants had had time to adapt themselves to their surroundings by growing thick woolly hair to keep out the cold and learning how to live on pine-trees. The body of a woolly-haired rhinoceros was afterward found in the same district. A well-preserved skeleton of the same species of mammoth was discovered during the digging out of the foundations for the *Daily Chronicle* offices in Fleet Street, London. From the depth at which it was found, and the nature of the deposits

lying above it, this mammoth must have been buried many thousands of years before the Romans came to Britain.

In January 1927 the skull of a hippopotamus was found in the red drift of the Pleistocene Period, fifteen feet below the site of the L.M.S. railway-station at Coundon Road, Coventry.

In 1715 a Palæolithic flint implement was found near Gray's Inn Lane, London, associated with the skeleton of a mammoth. It was immediately sent to the British Museum, where it lay for a hundred and fifty years before anybody understood what it meant, namely, that men who made flint implements had hunted mammoths in the London area twenty thousand years ago.

In July 1927, after years of highly delicate work, the task of mounting the Upnor elephant at the Natural History Museum, South Kensington, was completed. This is an example of the straight-tusked elephant, larger than the mammoth, which was found at Upnor, on the Medway, near Rochester, where it had been deposited during a warm period preceding the Ice Age. The skeleton was accidentally discovered by a party of Royal Engineers in the cutting of a practice trench, during which much of it was destroyed. The attention of the British Museum was not drawn to the bones until two years after the find, and when the bones were extracted, under the supervision of the late Dr C. W. Andrews, they were found to be exceedingly fragile, and riddled with roots and worm holes. It was impossible to save the skull, which crumbled away. The work of hardening, cleaning, restoring, and mounting the bones

has continued since then, at a cost of many thousands of pounds. A remarkable feature of the skeleton is that the width of the pelvis, six feet, exceeds any other similar measurement known. A tusk too shattered for mounting, the teeth, and the remains of a pig, hyena, and deer, found with the elephant, are shown in a table-case near the mounted skeleton.

CHAPTER III

DOWN A COAL-PIT

A COAL-PIT is very like a quarry, except that it is underground in complete darkness. A big modern pit is like an underground town, with miles of main streets lit by electric light, along the middle of which run narrow railways bearing trains of trucks, empty and full, always running backward and forward, being drawn along by endless cables running on pulleys in the floor. The side-streets, which run off at right angles every quarter of a mile, have also their two lines of rails, about two feet broad, and their trucks pulled along by haulage ropes, but these side-roads are only high enough for a man to stand up in, and only broad enough for the trucks to pass. Manholes or safety-places are cut out of the rock on each side of the lines of rails for a miner to get into and let a train of trucks pass him. In pits that are intended to last for a long time separate travelling roads are made for the miners, to avoid the risk of their being run over by the trains of trucks. Everything is in black darkness. There are no lights on the moving trucks, and the tiny, smoky little oil-lamps in the miners' caps often go out.

From these side-roads very narrow, low passages lead into the working-places. They have one line of rails, on which the little trucks are pushed by boys, or drawn along by pit ponies little bigger than a large dog. The

roof is very low everywhere, because the coal seam is usually only from two to five feet thick, and it is wedged in between hard rocks above and below it. It would take a lot of work to get this useless stone quarried out, carried along for miles and hauled up to the pit-head, and then to a rubbish heap; so it is left alone as far

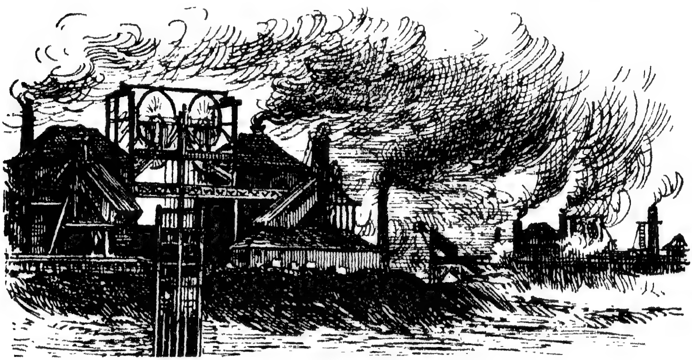


FIG. 8. A COAL-PIT

as possible. Narrow passages are cut down into the floor or 'pavement,' or up into the roof after the coal has been removed, so that the miners may be able to get into the rest of the coal seam and work out the coal. The roof is kept up by rows of wooden props at each side of the passage, and the pieces of rock that are cut out of the roof to make the pathway high enough are built into a wall at the sides, to help to support the roof.

You have often seen the high triangular supports for the winding-wheels standing above the mouth of a

coal-pit as you passed in the train, and perhaps you have watched the great wheels going round and round, and wondered what was going on in the ground below them.

A pit-cage is very like a passenger lift in the big shops, except that there are no velvet-cushioned seats and no mirrors, and it goes down six hundred feet instead of sixty. The ends of the cage are open, so that you can see the walls of the pit-shaft flying up past you as the cage goes rapidly down, down, down. When the cage stops at the pit bottom, and the gate is opened, you step out into black darkness. Then you see little lights moving about with men's voices coming from underneath them, and you realize that the lights are in the miners' caps. Presently there is a rumbling noise drawing nearer, and a pit pony comes along pulling a little train of loaded coal-hutches to be sent up the shaft you have come down.

The pit ponies are stabled in the mine, and spend their whole lives there, without ever seeing the daylight, except during their week of summer holidays. The horse has the keenest hearing of all animals. In pit ponies this sense is developed to a marvellous extent. Every old miner can tell you of a time when his own life was saved by a pony who refused to go on into a dangerous place, although the miner himself thought it was safe. Undoubtedly the ponies can detect dangers long before the men, and a careful miner will go to see what is wrong whenever he hears the ponies making an unusual noise.

Great care has to be taken to secure proper ventila-

tion for a mine. Indeed, it costs almost as much to ventilate and drain a pit as to sink it. Some mines raise twenty-five tons of water for every ton of coal brought up.

While dealing with the Carboniferous Period we saw that the carbonic acid gas and other gases, some of them very inflammable and explosive, arising from decaying vegetable matter have been bottled up in the coal seams for millions of years. These gases are still confined in the rocks under great pressure, and are always ready to burst out through any crack. Outbursts of gas have occurred in Scotland blowing out two thousand five hundred tons of coal at a time into the main roadways. There was no explosion. The rocks were forced out simply by the pressure of the imprisoned gases behind them. These imprisoned gases must all be got out and carried away before the miners begin work. Otherwise the men may be poisoned, or the whole pit destroyed by explosions of inflammable gases. Air will not go into a passage with a closed end. When a mine is being driven, therefore, a big wooden or canvas pipe has to be constructed along the passage, through which fresh air is forced to the men who are working at the far end of it. The used air finds its way back along the passages and up the shaft, taking the gases along with it.

Fresh air has to be carried right into the working-place of every miner in a pit, in the same way that air has to be pumped down to a diver working under the sea, as the one is in as unnatural a place as the other. To avoid having to construct and constantly inspect,

repair, and clean miles and miles of air tubes, and especially to avoid the risk of the miners being suffocated, or the pit being wrecked by an explosion if anything happened to go wrong with the ventilating pipes, the passages are so planned out that they connect with one another, and can all be used as big fresh-air pipes to carry air to the miners.

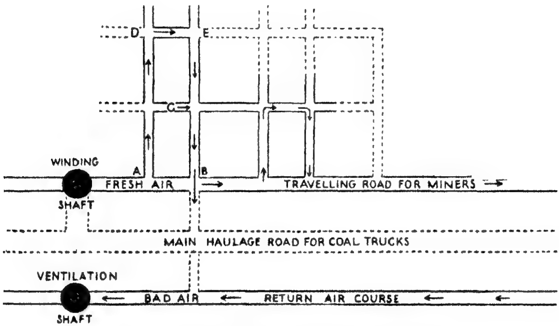


FIG. 9. HOW A MINE IS VENTILATED

Before any passage is driven into a new part of the mine the mining engineer has planned another passage which will meet it at the far end, and give a supply of fresh air.

As soon as the coal-winding shaft has been sunk and it is found that coal is really there a second shaft is sunk some little distance away to ventilate the mine, and to provide a means of escape for the miners if anything goes wrong with the coal-working shaft. Air is forced down the coal-winding shaft by a powerful steam fan. Then it runs along a passage underground and comes up the ventilation shaft. The workings of the pit are so

planned that all the main streets receive a plentiful supply of fresh air from this ventilating passage. All the crossroads are driven off the main roads in pairs, *A* and *B* (Fig. 9); then, as soon as they have gone a certain distance, they are connected by a cross-passage, *C*, so that the fresh air can flow along road *A*, across by level *C*, and flow back along road *B*. Then road *A* is continued to *D*, and road *B* to *E*, and another cross-passage is cut between *D* and *E*, and so on, until the whole area of the mine is connected by this network of passages. There is a set of canvas curtains or screens at every corner where

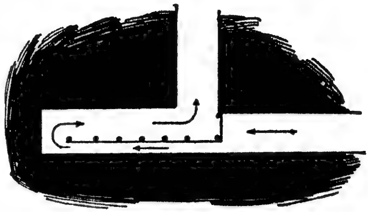


FIG. 10. PLAN OF BRATTICING

Canvas screens to direct currents of air.

From "The Black Diamond Reader," by Henry Briggs (T. Nelson and Sons, Ltd.)

FIG. 11. SECTION ALONG A ROAD, SHOWING BRATTICING

From "The Black Diamond Reader," by Henry Briggs (T. Nelson and Sons, Ltd.)

one main passage crosses another, so that a door can be shut in the face of the fresh-air current. It is thus forced to go up a crossroad and through a connecting passage, to flow back by another crossroad. In this way a current of fresh air can be sent into any part of the mine where it is needed.

Now we must remember that, just as the diver works under the sea, the miner is working below the level of the water, and that he would very soon be drowned unless artificial means were constantly used to prevent the water from accumulating.

The diver in the sea has fresh air pumped down to him as the miner has, and he is kept from drowning by being inside an indiarubber bag, called a diving-suit, which keeps out the water.

The miner is working in the bottom of a well hundreds of feet deep. Theoretically, it would be possible to keep him dry by cementing up all the cracks in the roof and walls of the mine, thus keeping the water out. The practical way, however, is to let the water come in as fast as it likes, keeping, at the same time, powerful pumps going, that pump it out again as soon as it comes in.

In planning out a mine advantage is taken of the natural dip of the strata (see Fig. 7). The shaft is sunk down to the lowest part of the coal seam, so that the water will run down all the crossroads into a big pond or well at the foot of the shaft, from which it is pumped to the surface. For cheapness, the shaft is often sunk so that two-thirds of the coal will be to the rise and one-third to the dip, and a drain-pipe is run to the bottom of the dip.

The natural slope of the coal seam is also used to carry the coal to the shaft bottom and to take back the empty hutches to the working-places. A pulley is set up in the working-place at the top of the incline, and a rope goes round it. An empty truck is fastened to this

rope at the foot of the incline, and as soon as a full truck is ready the top end of the rope is hooked on to it, and as the full truck runs slowly down the incline it pulls the empty one up to the working-place.

Most of the mines now are worked on the long-wall system, the 'long wall' being the face of the coal as it is exposed across the whole breadth of the seam. As

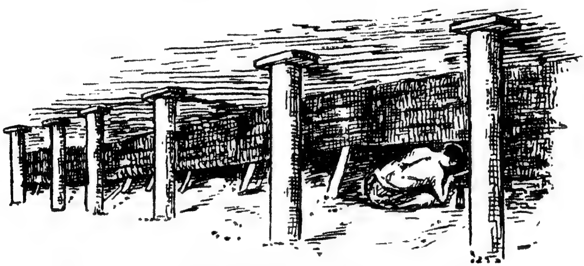


FIG. 12. UNDERCUTTING AT A LONG-WALL FACE
From "The Black Diamond Reader," by Henry Briggs
(T. Nelson and Sons, Ltd.)

soon as the shaft is sunk down to the seam level roads are cut in the coal to the boundary of the 'district' of coal that is to be worked. The miners cut crossroads to join the ends of the main roads, then they turn round and work backward toward the shaft. The whole seam of coal is completely removed, and the pit-props withdrawn, to be used again, and the roof is allowed to fall down into the empty space the miners leave behind them. The roof of the mine cracks up, owing to the weight of the thousands of tons of rock resting on top of it, and tumbles down in huge masses on to the floor. The stratum of rocks above the roof then falls down

into the empty space left by the roof when it fell to the floor. The rocks above settle down into this empty space, and so on right up to the surface. If there is a very strong layer of rocks somewhere between the worked-out, empty coal seam and the surface it may stand for fifty or a hundred years, and then snap and fall down suddenly, causing a little earthquake, and frightening the people living above it, especially if they

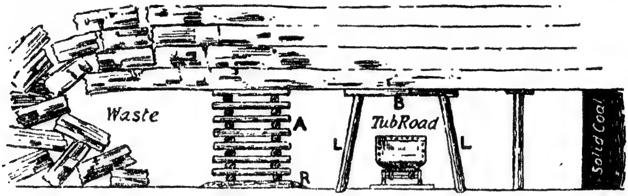


FIG. 13. SECTION ACROSS A 'LIFT'
From "The Black Diamond Reader," by Henry Briggs (T. Nelson and Sons, Ltd.)

happen to be sleeping when the walls of their houses crack and the windows rattle or break and the doors fly open.

Coal is much softer and more easily split than sandstone, but it is much more difficult to get at. One layer of sandstone comes away quite easily from the layer below it, and it is soon cut up into building-blocks, but the coal is wedged in tightly between other rocks, and you can only get at one edge of it. You do not want to blast out the coal, because, in doing so, you would break a great deal of it into tiny fragments. This would be wasteful. You must try to get the coal out in as large pieces as possible. In order to do this the miner

lies on his side on the floor and picks out a narrow cut at the bottom of the seam of coal, as far in as he can get

FIG. 14. MINERS ENGAGED IN UNDERCUTTING

with his pick (see Fig. 14). If the coal is very soft he may get it to come away from the roof by levering it down with a crowbar after he has cut the hole under it. If it is hard he bores holes in the top of the seam of coal, just under the roof rock, puts in small charges of gunpowder, and blows down the coal. In soft seams, if the coal is left hanging after the thin slice has been picked out from underneath, it will gradually break along its natural lines of cleavage, and then can be easily removed. For this reason the miner usually

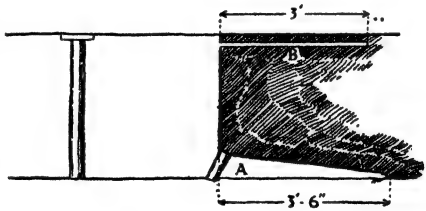


FIG. 15. SECTION ACROSS A COAL FACE, SHOWING THE UNDERCUT (A) AND SHOT-HOLE (B)

From "The Black Diamond Reader," by Henry Briggs (T. Nelson and Sons, Ltd.)

works his eight hours in 'undercutting' or 'holing' the coal. Then he leaves it till the next day, by which time it has cracked and largely broken up naturally, and is easily removed and filled into the little trucks. The miner then puts in a row of pit-props to keep the roof, from under which he has taken out the coal, from falling down on top of him. After this he begins his day's work of undercutting or holing the coal again.

Coal-cutting machines are now used in all modern pits, especially if the seams of coal are thin. A coal-cutter is like a big circular saw, similar to those used for cutting wood, but it works horizontally instead of vertically, and, instead of having teeth cut out of the edge of a round steel plate, it consists of a thin wheel with teeth—which can be removed to be sharpened—fixed into its edge. The coal-cutting wheel is driven by electricity, and is mounted on a low carriage, which runs on a set of rails laid along the face of the seam of coal. As the coal-cutter moves along it saws a narrow slit into the bottom of the seam of coal, in much the same way that a joiner saws through a plank of wood with a hand-saw. A coal-cutter moves along and saws in underneath about a hundred yards of the coal seam each

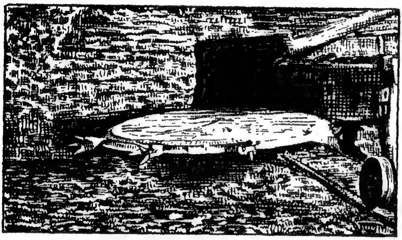


FIG. 16. A COAL-CUTTER

time, and the cut is usually from three to six feet in depth.

In the newest coal-cutters the wheel is replaced by an endless chain, with cutting teeth attached to it mounted on a long arm.

A coal-pit is a healthy, comfortable place to work in if it is properly drained and ventilated. It is dark, of course, but it can be made quite dry, and the air kept perfectly fresh. A miner can have as many lights as he likes to pay for, and there is no danger of the roof falling down if he puts in plenty of pit-props. These the pit manager is bound by law to give him for nothing.

The miner is not paid for putting in pit-props, however, and he thinks it a waste of time to put in too many. If he thinks the roof will stay up without a prop long enough to let him get his work done he just chances it. He may know that a bit of the roof rock is unsafe and ought to have had a pit-prop put underneath it, but the man that comes after him does not know this, and that is how accidents happen.

Water is honest, and will always run away downhill if you make a channel for it. You can see it, and you know exactly what will happen if you do not attend to it, but you cannot see bad air, and it is quite a long time before you are aware of its presence.

Air is horribly tricky stuff to work with, and you can never really understand all the forces which are acting on it. If the mine-workings were level it would not be so complicated, but they are generally on the slope. As heated air is always going up and cold air always flowing

down, bad air is always collecting in some corner or another.

It is easy to say that you have only to force in plenty of fresh air under sufficient pressure, and it is bound to blow the bad air out. The problem is how to maintain a supply of fresh air at the end of a long zigzag of passages, a mile away from the foot of the shaft. If any one of the doors used for directing the flow of air along the cross-passages is open when it ought to be shut, or if the fresh air gets away through holes in the sides of the passages, it will never reach the place where you want to send it. The whole mine is filled with compressed fresh air, which is blown down by the big steam-fan at the top of the shaft. But if you increase the pressure sufficiently to expel the bad air from the far end of a long passage the men working near the place where the cold air comes down the mine will protest very forcibly that the excessive fresh air is making it far too cold for them.

It might be necessary to drive a new air-course, to ventilate that part of the mine. As this would be extremely costly, the manager sometimes thinks that it would be cheaper to pay the men a shilling a ton extra for working in the bad air. Thus the men are often tempted, by this means, to work in places which are very bad for their health. As there is danger of the miners thus ruining their health through working in bad air, Government inspectors are appointed to go down the mines regularly, and not only see that they are properly ventilated, but that all the other regulations for securing the safety of the miners are obeyed.

When there is only an odd corner of coal left to be taken out, it might easily cost more money to ensure proper ventilation than the coal is worth. If the miners will not work it the coal is lost altogether. It is better for the manager to pay extra wages than to lose that coal ; but the miner is always afraid that if he agrees to work in bad air in that particular place he will have to work in bad air in other places without getting any extra pay. The Government inspector of mines is often called in to settle such disputes.

The sudden havoc of an explosion makes people forget that the total number of deaths caused by explosions is very small when compared with the number of miners killed or disabled by pieces of rock falling from the roof and similar accidents. The effect of the explosion is greatly increased by the fact that it takes place inside a bottle, for every mine is like a big fragile bottle, exceedingly wide at the bottom, but with a long and very narrow neck which is extremely liable to get broken or choked up. If the mine floor were as small as your class-room, for instance, then the pit-shaft would be thinner, in proportion, than the lead inside a lead pencil. Pit-shafts are from 500 to 5000 feet deep, and are constantly being squeezed in from all sides, and undermined by the underground waters.

It is the closing up of the air-passages by falls of rock from the roof, and the consequent slow poisoning by bad air, that accounts for the deaths of the great majority of the miners killed by an explosion. The whole of the coal-field is not being worked at once, and it is only the sections which are being worked that are

kept ventilated. Each working section is like a big indiarubber bag with a long pipe, down which air is pumped to the miners working inside it. To understand what happens when there is an explosion or a big fall from the roof you must imagine that your class-room floor is covered with indiarubber hot-water bottles all connected by branching tubes with one another, and with an air-pumping machine which keeps all the working sections inflated. If any one of these many passages is burst by an explosion, or closed up by a fall of rock, then the working of the whole ventilating system may be destroyed, and every miner who cannot escape from the mine will be slowly suffocated.

There are so many inter-communicating passages and connexions with old workings that miners never give up hope of rescuing a comrade till they have actually found his dead body, and, on the other hand, there are so many ways in which bad air may steal into a working-place that an underground manager never leaves his job till every miner that came down the pit on that shift has been accounted for.

Oxygen gas is absolutely necessary for all animal life, but it is such a powerful chemical that our bodies can absorb it only in very small doses, which we need to take into our lungs about sixteen times every minute. Oxygen has to be diluted with nearly four times its volume of an inert gas called nitrogen to prevent it from injuring our lungs. This nitrogen gas is not of any direct use to us. It simply carries and dilutes the oxygen, enabling us to breathe the mixture without harm. We breathe out, unaltered, 99½ per cent. of

the air we take in. Pure fresh air contains 20·96 per cent. of oxygen, 79 per cent. of nitrogen, and ·04 per cent. of carbonic acid gas. It is of great importance to human life that these gases should be mixed in exactly the right proportions. If the mixture of oxygen is too weak then our blood cannot absorb any of it at all. If there were even one-quarter too little oxygen in the mixture we breathed we should die—the remaining three-quarters would be of no use to us.

The Coal Mines Act, therefore, declares that air which contains less than 19 per cent. of oxygen, or more than 1¼ per cent. of carbonic acid gas, is poisonous, and must not be breathed. All work must be stopped, and the men must not even be allowed to walk through any part of a mine when there is even 2 per cent.—that is, one-fiftieth—too little oxygen in the air.

The miners' great enemies are carelessness (which causes more than three-quarters of all the accidents), coal-dust, firedamp, black-damp, and after-damp.

Dry coal-dust is as dangerous as gunpowder, and causes more than three-quarters of the explosions. With air it forms an explosive mixture. Fortunately most pits are damp, and it is easy to arrange the drainage so that all the roads and most of the walls of the pit can be kept damp. In this way coal-dust is prevented from floating about in the air. Dry pits should be continually swept clean, and frequently coated over with moist stone-dust, which prevents explosions in the same way that sand puts out fire.

Firedamp is marsh-gas, a combination of hydrogen and carbon formed by decaying vegetation. It exudes

from the coal seams. It is not inflammable if there is less than $5\frac{1}{2}$ per cent. or more than 15 per cent. mixed with the air of the pit. It is lighter than air, and collects in holes in the roof. Very small quantities of it are easily detected by the use of a safety-lamp, and it can soon be blown away.

Black-damp is not carbonic acid gas or any other distinct kind of gas; it is simply air with too little oxygen in it. Miners say there is black-damp in the air when their lights go out. The lights go out because there is not enough oxygen in the air-mixture to keep them burning, but, instead of saying that there is too little oxygen in the air, the miners say that there is too much of the useless gases nitrogen and carbonic acid in it. This excessive quantity of nitrogen or carbonic acid is spoken of as the quantity of black-damp in the air. Cold is the absence of heat, and black-damp is the absence of oxygen. Black-damp will kill you, just as cold will kill you. Whenever your light is put out by bad air in a pit turn back, and go no farther, or the want of oxygen may put your life out too.

White-damp is the miner's name for carbon monoxide. This is a very poisonous gas, which is produced when coal or timber or firedamp burns with a restricted supply of oxygen.

After-damp is the name given to the mixture of poisonous gases which results from an explosion of firedamp.

Gold, silver, copper, lead, tin, and other metal-mines are very similar to coal-mines, except that their mineral seam is usually vertical, instead of horizontal. The

ores of these metals are usually found in quartz veins, which fill up great cracks in the rocks running across the country for miles and miles, and extending from the

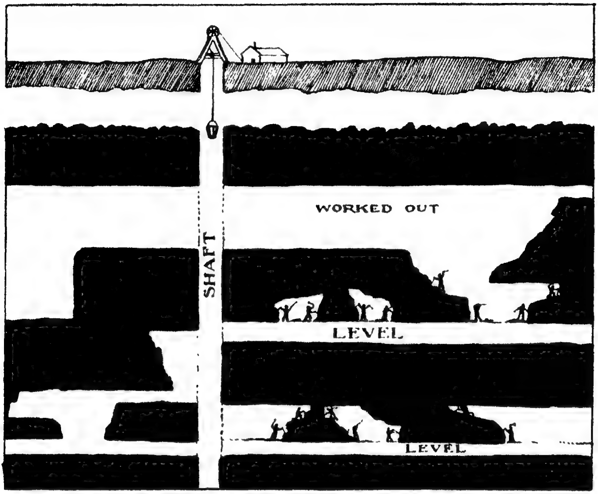


FIG. 17. SECTION OF A LEAD-MINE ALONG THE VEIN
This is what the mine would look like if the hill were split through along the vein and one side of the hill were lifted away.

surface toward the centre of the earth. They are like a coal seam standing up on its edge, instead of being spread out flat, and consequently the different working-places are connected by upright ladders instead of by passages.

CHAPTER IV

THE FLUID EARTH

> The hills are shadows, and they flow
> From form to form, and nothing stands;
> They melt like mists, the solid lands,
> Like clouds they shape themselves and go.
>
> TENNYSON, *In Memoriam*

WE think that the earth is solid, and that its mountains have been ever the same. People say that a thing is "as old as the hills," because they think of the hills as the oldest and most enduring things in the world. Geologists have proved, however, that the crust of the earth on which we live is as thin and unstable as the scum of dust on a plumber's hot lead-pot, which he blows aside before pouring out the lead, and that our world is a big drop of melted rock, a hundred times hotter than the melted lead, flying through space with terrific speed.

The rocks on the tops of the mountains contain the fossil remains of animals that lived in the sea, and therefore these rocks must have been formed at the bottom of the sea.

You refuse to believe this, and ask me how the sea can ever have been deep enough to cover up the tops of the mountains. I answer that the sea-level is the one thing that never changes, but the mountains sink beneath the sea, and the rocks at the bottom of the sea rise up and become mountains.

You say that you are not going to believe that the mountains have risen from the sea, simply because I've found some cockleshells in the rocks on the top of the mountains; and that there must be some far simpler and more probable explanation of the cockleshells than that.

I am not surprised at your saying this, because the Greek scientists over two thousand years ago found and described the fossil shells, and realized what they were, but no one had imagination enough to believe that the sea-bottom could rise up and become mountains.

We all believe now that the world is a round ball, but we don't realize how thin its skin is. We know that in whatever part of the world we sink a mine the internal heat of the earth constantly and regularly increases the deeper we get down, so that at a depth of twenty miles the heat must be great enough to melt all the rocks inside the earth. The skin of the earth cannot therefore be more than twenty miles thick, and we know that in the volcanic regions it is exceedingly thin, and that the white-hot melted rocks underneath are constantly bursting through whenever they can find a weak spot or a crack in the crust.

If I had an indiarubber ball bigger than myself, so that I could stand up inside it, to represent the size of the earth, then its skin would have to be less than one-sixth of an inch thick to show the thickness of the earth's crust. If you can imagine a soft felt hat growing into a globe six feet in diameter, with the felt at the same thickness, you would have

a good idea of the thinness and instability of the earth's crust.

Starting outward from the centre of the earth, we should pass through 3980 miles of melted rocks heated many times hotter than molten iron—though kept solid by the enormous pressure upon them—and twenty miles of cold rocks before we came to the surface.

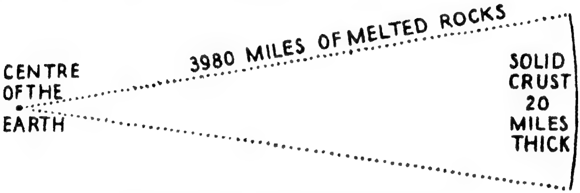


FIG. 18. SECTION OF THE EARTH

A pricked indiarubber ball won't bounce, because some of the inside air has escaped. There is always a depression in it somewhere, and its surface is unstable. Our earth is like this pricked ball. Its skin is too big for it. This is not because any of the liquid inside it has escaped, but because the whole of the earth is growing colder, and when any body grows colder it shrinks, and folds itself into a smaller space. Some parts of the earth's surface are always sinking down, and when they fall below the level of the sea the sea rushes in over them to fill up the hollow. When I push in any part of this ball you see it rises up in another part. In the same way some parts of the earth's surface are being raised up at the present time, and other parts are being crushed in. If such a disturbance of the earth's surface caused the whole of Europe to sink below the level of

the sea, and if the bottom of the Atlantic Ocean were to rise up and become dry land, even this tremendous change would not be as great a change, in comparison with the size of the earth, as if I were to press in the skin of this rubber ball with my finger ever so slightly.

To realize how small a thing a mountain is compared with the rest of the world, we'll try an experiment. If we imagine the world to be as big as a dining-table, how high do you think the highest mountains in the world would stand in comparison with the height of the dining-table? What would you place on the table to represent the height of Mount Everest, the highest mountain in the world—a tumbler, a salt-cellar, a biscuit, or a postage-stamp?

Don't waste time wondering and guessing, when you can easily find it out for yourself. How high is Mount Everest? Nearly 30,000 feet. How high is the world? 8000 miles. How high is the table? Thirty inches.

$$\frac{8000 \times 1760 \times 3}{30,000} = 1408.$$

The world is 1408 times as high as Mount Everest.

How high is the 1408th part of thirty inches? One-forty-seventh of an inch.

So that to represent Mount Everest on the height of the table you would need something just a little thicker than a postage-stamp.

The average height of all the land above sea-level is less than a half-mile, or less than one-tenth the height of Mount Everest. So that a sheet of tissue-paper, the five-hundredth part of an inch thick, laid on the table,

would represent the average height of the land above the level of the sea. You can understand what a very little movement it would require to raise one part of the table the five-hundredth part of an inch and make it dry land, or to lower it the five-hundredth part of an inch and make it sea.

So you can see that, compared with the size of the earth, the amount of rising or sinking of the earth's crust which is needed to make the sea dry land, and to bury the mountains under the sea, is very small indeed.

If the sea were to rise a thousand feet, or even five hundred feet, you would be surprised to find what a small part of Europe would be left. The whole history of the world would have been different if the North Sea had been a hundred yards shallower (see Fig. 19). Then England would have been joined to Europe in two or three places, and would probably never have existed as a separate nation. It is almost impossible for us to think of what the history of Europe would have been if England and Scotland had not been separated from the mainland.

In comparatively recent times, considering the age of the world, the Thames and the Humber, the Tweed and the Forth, were tributaries of the Rhine, which flowed through the North Sea Plain and cut out a deep estuary round Scandinavia, where the water quite close to the shore is still as deep as the Atlantic Ocean.

The average height of the land above sea-level is 2300 feet, or rather less than half a mile. You remember the piece of tissue-paper, a five-hundredth of an inch thick, laid on the table to represent the average

height of the land above the level of the sea. Well, if you wished to show the depth of the oceans as compared with the thickness of the earth, you could breathe lightly on the polished top of the table. The thickness of that film of moisture compared with the height of the table would stand for the depth of the oceans compared with the thickness of the earth.

We are so often told that the sea covers three-quarters of the surface of the earth, and that the dry land is only one-quarter, that we need to be reminded sometimes that after all the sea is not deep.

I want you to get thoroughly accustomed to the idea of the land sinking below the level of the sea, and the sea-bottom rising into mountains, as this alternate rising and sinking of the earth's surface is the most important fact for students of geology. The slow progress that the science of geology has made, although all the facts on which it is founded have been lying bare, staring men in the face for thousands of years, is mainly due to the mistaken idea that the land has always been separate and distinct from the sea.

In reality, land and sea have been moving up and down, as if playing see-saw with each other, ever since the world came into existence.

Greek and Roman writers had observed fossil sea-shells in the rocks on the tops of mountains, but while they saw at once that the fossil shells were the same as the shells on the seashore, it never occurred to them that the sea had once rolled over these mountains, and they tried to account for the fossil shells by all sorts of strange theories.

Leonardo da Vinci, the painter of the famous picture of the Last Supper, who was a great civil engineer as well as an artist, discovered hundreds of fossils during his excavations. He was the first to see their true nature, but nobody would believe him or accept his explanation. Men clung on so determinedly to the idea that the deluge in the time of Noah was the only deluge that geology made very little progress till the beginning of last century.

Figs. 19 and 20 are two maps which I have shaded to show what this part of the world would look like if the sea rose or fell three hundred feet.

Fig. 19 shows North-western Europe with the sea-level 300 feet lower than it is at present. The North Sea has disappeared. You could walk on dry land from Spain to far beyond the west coast of Ireland, then north to Shetland, and across the North Sea Plain to Denmark. After that you could wander about the great valleys now filled by the Baltic Sea and the Gulf of Finland, and then walk back to France.

Look now at the other map (Fig. 20) and see what would happen to England if the sea rose 300 feet. Three-quarters of the country and over 30,000,000 of its people would be drowned. Not only all our flourishing seaports, but London, Manchester, and other great manufacturing centres would disappear; and the salt waves would roll over the roofs of Hexham, Durham, York, Darlington, Leeds, Sheffield, Lincoln, Derby, Nottingham, Coventry, Grantham, Leicester, Peterborough, Bedford, Oxford, Cambridge, Reading,

FIG. 19. NORTH-WESTERN EUROPE WITH THE SEA-LEVEL 300 FEET LOWER THAN IT IS NOW

Salisbury, Exeter, Winchester, Bristol, Worcester, Shrewsbury, Gloucester, Stafford, Wrexham, Burton-on-Trent, Chester, Crewe, and many others of our largest inland towns.

The Pennine Chain, the backbone of England, would form a peninsula running from Birmingham up into Scotland. Wales and Devon would be islands, and "the English Archipelago" would be the name given to the four rows of islands that were formerly the Cotswold Hills, the Chiltern Hills, and the North and South Downs.

The division of the Old World into Europe, Asia, and Africa is purely artificial, and very modern. The early inhabitants of Northern Africa were just as white as you are. Geology has proved what the study of the races and languages of the world had led us to suspect, namely, that the northern part of Africa once formed part of Europe, and was separated from the southern part of Africa by a sea which connected the Atlantic with the Indian Ocean, and covered the great Sahara Desert.

To go back to our simile of the wobbly india-rubber ball, we may say that in quite recent times—speaking geologically—some movement inside the earth caused the outside skin to wobble, with the result that the Sahara Desert was raised out of the Atlantic and Indian Oceans. To compensate for this rising of the earth's skin under the Sahara there had to be a sinking somewhere else. The land which formerly extended between Southern Europe and Northern Africa sank, and the Atlantic Ocean flowed into this

depression and formed the Mediterranean Sea, as we now know it.

If you look at the map of the Eurafrican Continent, and compare it with the submarine plateau of Austral-

FIG. 20. SUBMERGED ENGLAND IF THE SEA-LEVEL ROSE 300 FEET

asia and the sketches showing the effect of the sea round England falling or rising a hundred yards, you will understand how it is possible for geologists to reconstruct the country now lying under the Mediterranean Sea.

The Atlas Mountains in North Africa are geologically

the same as the mountains of the rest of Europe. The sea between Spain and Africa is still shallow. The peninsula of Italy is a half-drowned range of mountains, which ran from the northern to the southern part of the

FIG. 21. RELIEF SKETCH OF MALAY ARCHIPELAGO, AUSTRALIA, AND ADJACENT ISLANDS, SHOWING (IN WHITE) THE SHALLOW SEAS SURROUNDING THEM

Eurafrican Continent. The islands of Sicily and Malta are parts of this range, still above water. Crete and Cyprus are drowned mountains. The terrible earthquakes which devastated the country round Messina, and the renewed activity of Mount Vesuvius, are further proofs of the newness and instability of this part of the earth's crust.

The Black Sea and the Caspian were the southern-

most bays of the great Northern Ocean, which rolled over the plains of Russia and Siberia. For a considerable time after man had appeared on the earth India and Arabia were islands, which have since been united to the mainland by banks of sand and gravel, brought

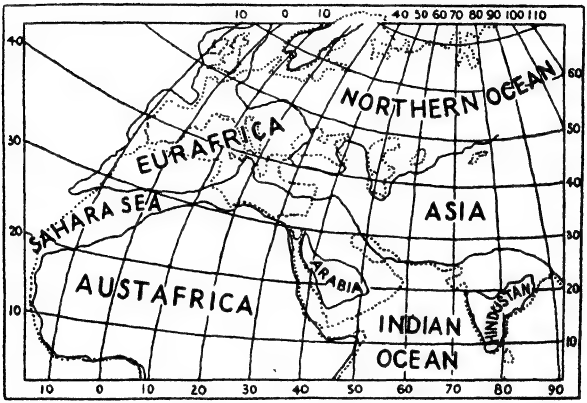


FIG. 22. EURAFRICAN CONTINENT. OUTLINES OF THE EASTERN HEMISPHERE IN THE EARLY QUATERNARY PERIOD, WHEN MAN FIRST APPEARED ON THE EARTH

The present continents are shown in dotted lines.

down by the great rivers and deposited when they reached the sea.

The early home of all the white races was in Eurasia. Possibly it is now lying beneath the waters of the Mediterranean, and this may account for the fact that every one of the Aryan nations, from Ireland to India, has its distinct traditions of a flood which destroyed the ancient world.

Plato's description of the lost island of Atlantis,

which is still perpetuated in the name 'Atlantic,' has had a fascination for writers and thinkers ever since it was written. Ingenious commentators have tried to locate it in almost every country in the world, and there is no doubt it stimulated many of the navigators and discoverers of the sixteenth century.

In his dialogue at Sais, the capital of Egypt 2500 years ago, Plato makes the old priest of Neith say to Solon, the founder of Athens:

"As for these genealogies of yours which you have recounted to us, Solon, they are no better than the tales of children, for, in the first place, you remember one deluge only, whereas there were many of them."

It is very remarkable to find such a distinct and emphatic statement that there have been not merely one, but many deluges made at so early a period in the world's history, and I have often wondered how far the science of geology might have been advanced if the wise men of old who founded their physical science on Plato had only grasped this fundamental idea of the frequent submergence and elevation of various parts of the earth's surface.

Through the depths of Loch Katrine the steed shall career,
O'er the peak of Ben-Lomond the galley shall steer,
And the rocks of Craig-Royston like icicles melt,
Ere our wrongs be forgot, or our vengeance unfelt!

SIR WALTER SCOTT, *MacGregor's Gathering*

CHAPTER V

SERAPIS

You should think of the earth being lightly clothed by the sea, like a boy who is wearing a very thin bathing-costume with numerous holes in it, so that his bare skin appears every here and there as islands or continents. Islands are mountains resting upon plains which happen to be covered by the sea at present; and estuaries like the Bristol Channel, the Clyde, the sea-lochs of the West of Scotland, and the fiords of Norway are valleys which have been drowned by the rising of the water, or, rather, by the sinking of the land below the level of the sea. In some parts of the world's surface the land is slowly rising above the level of the water, and in other places it is still sinking. This is well illustrated by the history of the temple of Serapis at Pozzuoli.

Marius, Pompey, and Julius Cæsar—who each in their turn conquered the world, made themselves masters of Rome, and died tragically—had country houses at Baiæ, and worshipped their gods in this temple. Often they must have walked beneath those colonnades, and looked out upon the still blue waters of the Bay.

There is a road that leads from Pozzuoli round the north-west corner of the Bay of Naples to Baiæ. On the right the ground rises toward Mount Solfatara,

which was once a very active volcano; on the left it slopes down to the border of rich land which fringes the sea.

Half-way between the road and the sea a marble column five feet high stood among some bushes. There are a great many noble ruins in that district, as it was the most fashionable seaside resort of the Romans when at the height of their power. Two hundred years ago a traveller saw the pillar. Nothing was known of any public building having existed at that place, so he wrote in his book that this fragment had probably come tumbling down the mountain from some ruin, and had stuck in the ground with its top end up. The traveller was a learned man, and all the tourists were told the same story, and all believed it.

In 1749 an observant stranger walked off the road, came and looked at the pillar for himself, and noticed that the top was quite level. He wandered round among the bushes and found the top of another pillar. He didn't understand how two pillars could have tumbled down a hill, and both stuck into the soil with their tops level. He poked about with his walking-stick, piercing the soft ground here and there, until he struck the buried top of a third pillar. He found it was in line with the first two, its top was level with their tops, and they were all the same distance apart. Then he said, "This is not the case of a pillar falling down a hill, but of a hill falling round a pillar"; and that if they were to dig down they would discover a great temple which had been buried for two thousand years. Excavations were made, and the ruins of a magnificent

temple were laid bare. It was seventy feet square and sixty feet high, the roof being supported by forty-six splendid granite and marble columns. The walls were decorated with beautiful panels of precious stones. But that was not the wonderful part of the story. When geologists examined the ruins they saw it clearly proved not only that forty feet of sediment had been laid down above them in two thousand years, but that the land on

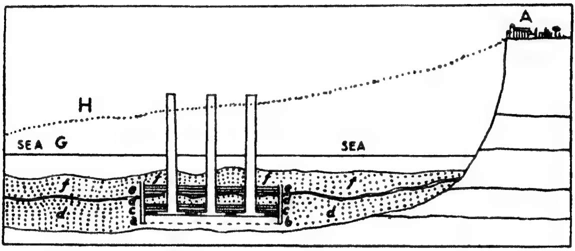


FIG. 23. SECTIONAL DIAGRAM OF THE RUINS AT POZZUOLI

A, site of Cicero's villa (in one of his letters he tells us he could catch fish out of his dining-room window). *ab*, ancient mosaic pavement. *cc*, dark marine incrustations. *d, d*, first filling up by showers of ashes. *ee*, fresh-water calcareous deposit. *f, f*, second filling up by showers of ashes. G, sea-level when lithodomus borings were made. H, level of accumulated rubbish which had fallen down mountain and buried temple.

which the temple was built had sunk at least five feet under the sea, and remained at that level for several hundred years. Then it had gradually sunk down another twenty feet and rested there over six hundred years. Finally a great earthquake raised the whole sea-bottom more than twenty-six feet, so that the temple once more stood on dry land.

Since the beginning of last century the land has been steadily sinking again, till now the pavement of the

temple is about six feet under water. An architect who sketched and measured the ruins in 1814 went back twenty years later and found men catching fish inside the temple, and two or three feet of sea-water on the pavement where he had worked for days.

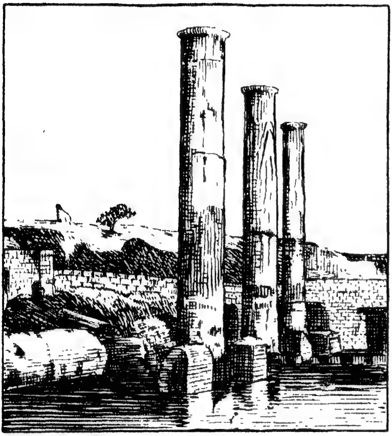


FIG. 24. THE TEMPLE OF SERAPIS

Now, what do you think gave the clue to this strange history? The lower halves of the marble columns are pitted with holes. These holes have been proved to be the burrows of a small sea-animal, the lithodomus mollusc. It is a cousin of the common edible mussel, about the same shape and size, and is named lithodomus (*lithos*='stone,' *domus*='house') from its habit of boring a hole for itself in the rock.

The tiny cave which the lithodomus hollows out for itself is pear-shaped, with the narrow end opening to the sea. The shellfish sits at its front door all day waiting for some unwary little animal to drift within reach. When it has taken in a sufficient number of visitors it shuts its shop, and retires to digest them.

The enterprising founder of this lithodomus colony discovered that the tall, slender marble pillar standing

by itself in deep water was a capital site for doing business, because far more tiny sea-creatures drifted near him than would have done if he had been located in an ordinary rock. He and his descendants industriously occupied the place for centuries, and pitted the pillars with innumerable holes, until the unthinking earth heaved up and hoisted the temple ruins right into the air.

Sir Charles Lyell tells us that when he first examined the ruins most of the pear-shaped holes had shells in them. You could put your finger in and move the shells about, and feel them all over, but you could not get them out of the hole, because the narrow entrance was not big enough to let your finger and the shells come out at the same time.

Marble is a hard crystalline rock, and the lithodomus is a flabby little animal without a single bone in its body. How, then, can it bore a cave?

You must remember that the mollusc is an animal just as you are, but it wears all its bones outside its flesh, while you have yours inside. You would admit this is true of a crab; so you can't deny it of a shellfish. Like you, the mussel eats other animals and plants, and breathes oxygen, which it finds dissolved in the water. You are constantly breathing out carbonic acid gas, and the mussel does the same. The carbonic acid gas acts on the marble and gradually softens it, then the mussel rubs off the softened rock with its 'foot' or tongue, and constantly enlarges its home. One result of this is that the lithodomus is imprisoned in the rock for life, like the old monk who had broken

his vow, and was built up alive into the wall of the monastery and fed once a day through a hole in a stone. The mollusc who has so indelibly written for us the strange history of this part of the world, which otherwise we should never have known, is in a much worse position than the mouse that squeezed its way through a small hole into the sugar-tin, and then ate so much that it couldn't get out again. Still, this imprisonment doesn't seem to worry the mollusc, for the fossil records show that it has gone on for millions of years just living and boring its holes into the rocks in the same way as it does to-day.

Excavations made in the centre of the temple have revealed a beautiful mosaic pavement five feet below the level of the present one, which must have been put in after the building had sunk so far that the old floor was covered by the sea-water and a new floor was needed to enable the temple to be used again.

The fact that these tall, fragile pillars have remained standing for over two thousand years, while the rest of the building has peacefully decayed away, shows that there has been no violent shaking of the ground.

Built on the shore overlooking the Bay of Naples, the temple gradually sank along with the surrounding country, till the waves crept up to it and lapped at its foundations. Year after year the land sank lower and lower. The tides flowed in and out among the bases of the columns, and the little sea-animals lived and died and left their shells sticking in the pillars, where we see them to-day. The columns are pitted with these holes up to a height of twenty-six feet from the

floor, and as they can only have been bored by the lithodomus when the pillars were under water these holes prove that the temple must for a considerable period have been sunk for twenty-six feet under the sea.

The land rested there under the sea for centuries till disturbed by the great earthquake in 1198. Then again, about the year 1538, the crust of the earth began to heave, and the ground gradually rose out of the sea. The subterranean forces pushed it up and up till once more the drowned and buried temple stood on the sea-shore and overlooked the Bay.

These earth movements were so gentle, and such a large area of the land moved at once, that the tall, slender pillars stood undisturbed. The holes in the marble show the fall and rise of the land between these two dates. Recent measurements prove that the country is once more sinking at the steady rate of nearly an inch a year.

I often think of those lonely columns and wonder how many worlds they are the survivors of. Millions of years ago, in the deep blue ocean, tiny little animals called foraminifera—that even under the microscope are mere specks of jelly—lived in the sunshine on the top of the warm water. Year after year these foraminifera died, and their tiny shells fell down like snowflakes through the clear still water, till they covered the bottom with a bed of ooze a hundred feet thick.

As age succeeded age, great mountain ranges on the adjacent continent were gradually eaten away by the raindrops and carried down the rivers grain by grain, and dropped farther and farther out till they covered

up the bed of shell-ooze lying on the floor of the ocean to a great depth.

It is impossible to calculate how many millions of years the tiny shells of the foraminifera, now crushed and changed into limestone, lay buried under the miles of newer rocks that were thus heaped up above them. Thousands of feet above these unborn mountains the ocean waves danced in the sunshine, and the rivers came bringing down their constant tribute of sand. These beds of newer rocks lying on top of the limestone acted like great blankets, which kept in the internal heat of the earth and helped to convert the crushed shells into marble.

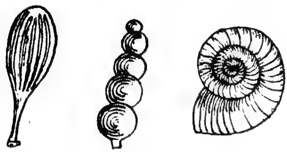


FIG. 25. FORAMINIFERA SHELLS
Greatly magnified.

One day the crust of the earth gave a great heave. The floor of the ocean slowly rose hundreds of feet into the air, and lay stretched out under the sun as a wide continental tableland.

While man was slowly rising in the scale of being the rivers were cutting their valleys out of this new continent. In the course of untold ages one of these rivers had carved its channel down through all the layers of the newer rocks, until it cut into the bed of marble lying in the bottom of its valley.

At length man wandered up the river valley, found the marble rock, and cut out these pillars for a temple to his god Serapis. The old foraminifera shells once more stood in the sunshine.

This temple for the worship of Serapis, the ruler of the dead, was built at Baiæ, because that district had, from time immemorial, been associated with strange manifestations of subterranean power. The grotto of the Cumæan Sibyl, the world-famed grove of Hecate, the goddess of ghosts and witches, and controller of the future, and the awful lake of Avernus, filling the crater of an extinct volcano, whose dark and sulphurous waters gave entrance both to the Underworld of Homer and the Elysian Fields of Virgil, were all within three miles, and the whole district seemed consecrated to the service of Pluto.

A modern geologist would point to Solfatara and Mount Vesuvius across the Bay and calmly lecture us on the theory of volcanoes.[1]

During an eruption such a large quantity of melted rock would pour out of the mountain that a great hollow would be left under the earth where the erupted material came from. The overhanging crust of the earth would eventually settle down into the empty space beneath it. This would cause the surface of the earth immediately above it to sink also, and the sea to flow over it. Before another eruption another great mass of volcanic material would have collected beneath the crust of the earth near the volcano. This would swell and float up the over-lying rocks, and the surface of the earth would rise again, only to sink once more after the eruption.

[1] There is a proposal to utilize the natural gases of Solfatara to generate electricity to run tram-cars and light Naples.

CHAPTER VI

THE SECRET OF THE HILLS

STANDING beside a river in the middle of its valley and looking up at the hills around us rising into the sky, as if to shut us in from all the rest of the world, I am not surprised that you refuse to believe that millions and millions of tons of solid rock once filled up the entire space between the hill-tops on either side of us; and that all this enormous mass has been carried into the sea by the tiny stream at our feet.

As long as you stay down in the valleys I needn't argue with you, for I should never convince you. But if you will climb to the top of the hills you will realize that the dozens of hill-tops you see standing round you are all parts of the one tableland, which has been cut across and across by river valleys, until it looks like a collection of separate hills.

Hills are the last remains of an elevated plain left standing by the rivers, which have gone on cutting valleys out of it until they have carried it nearly all away into the sea. The valleys were at first mere scratches on the top of the tableland. Year by year the rivers carved their way deeper into the land. The sides of the valley slipped down into the stream, and the force of the water carried this material right away to the sea.

The river valleys were constantly growing deeper and broader, and cutting their way back into the tableland.

The land between two valleys was eaten away on both sides, till from being a slowly vanishing area of country it became a narrow ridge between two great, wide valleys. The very memory of the former tableland passed away, and men said the rivers rose out of the hills. They thought that the hills and valleys had always been there, and that all the river did was to receive the rain that ran down the hillsides into it. They never imagined that the rivers had made the hills by carving out the valleys between them.

The elevated plains of which the hills are the remains were formed by movements of the earth's crust, which caused large parts of the surface to rise up from under the sea. If we liken the earth to a balloon from which some of the gas has escaped the high tablelands are the places where the loose skin of the earth has risen up out of the water.

You will understand it better after I have explained to you the origin of the great earth foldings which we now call ranges of mountains straggling in long broken lines right across the surface of the world. The map of the Western Hemisphere shows quite plainly that the Rocky Mountains in North America and the Andes in South America are great folds running down the west side of the continent for ten thousand miles.

Take a sheet of paper, fold back the margin, and stand it on the table.

Look at it endways, and you have a good model of North and South America, with its steep slope down into the Pacific, and its gradual descent toward the Atlantic. Press it down with your finger in the middle

of the ridge and the Atlantic Ocean will flow into the depression and form the Caribbean Sea, dividing the two halves of the continent. The surface of the Western Hemisphere was folded upward in much the

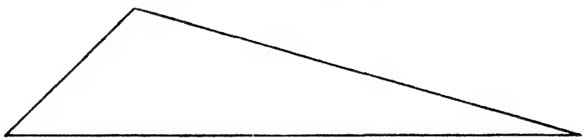


FIG. 26. END VIEW OF FOLDED PIECE OF PAPER

same way as this page, and the great rivers of America have since scratched their channels out of it.

The force that raised the immense ranges of the Andes and Rocky Mountains out of the bottom of the ocean right up into the air was the force of the earth's skin contracting in order to fit itself to its inside core, which had cooled, and therefore grown smaller. This force of contraction pulled the west and the east sides of the continent toward each other, and elevated the mountain ridge; just as you could cause the ridge of the folded sheet of paper to rise higher from the table by pushing the opposite sides of the paper together.

The west side of South America is exceedingly steep, and goes rapidly down many miles into about the deepest water in the world. The folding of the ridge is so sharp that the earth's crust seems to have been broken right through, and along this weak part we have a long line of lava out-flows and active volcanoes. Part of the coast of Chili is still rising out of the ocean. Earthquakes are of frequent occurrence. The one that

destroyed San Francisco was not remarkable for its intensity, but because it happened to strike a large modern city laid with gas pipes, and consequently caused immense damage to life and property.

In the Old World the crumplings of the earth's skin are much more complicated, but a good idea of their effect can be got by taking a map of Europe and Asia and folding it backward diagonally from corner to corner, first in a line from Bering Strait at the north-east of Siberia to the Strait of Bab-el-Mandeb at the south of the Red Sea; and, secondly, from the Pyrenees in the north of Spain to the north point of Borneo. Press down these folds tightly between your finger and thumb, running them inward from the corners toward the centre, and then raise the map so that it forms a flat pyramid with its apex in the Pamir Mountains, where these two lines intersect.

You have now got a very useful relief map of the four great divisions of the Old World. The line from the Gulf of Aden to Bering Strait is the great line of world mountain-folding, and forms the eternal barrier between East and West. (It would be more correct if you made another fold from the Pyrenees to the mouth of the Indus, and raised up the little triangle of high land between the Pyrenees, Indus, and the Pamirs, but this can be done afterward.)

Each of the four sides of the Eurasian pyramid, with its apex in the Pamirs, forms one of the great divisions of the Old World, geographically, racially, politically, and commercially. On the north we have the Siberian triangle, stretching from the Bay of Biscay to the Bering

Sea. It may seem startling to include Britain in the Siberian area, but Britain would have a Siberian climate were it not for the action of the warm currents from the Atlantic Ocean called the Gulf Stream. It is the Aden-to-Afghanistan, Himalayas-to-Bering Sea ring of mountain chains that shuts out the moisture-laden winds from the Indian and Pacific Oceans and makes all the country behind these ranges dried-up, lifeless deserts.

The Indian triangle is the exact opposite of the Siberian triangle in climate, race, politics, and productions; while the Chinese face of the pyramid on the east, and the Mediterranean face on the west, resemble one another very closely in climate and productions.

The high Central Asian Tableland is the most important geographical fact, as it has determined the whole history of the human race. During the Ice Age great accumulations of ice gathered there, and the history of the Siberian triangle, to which we belong, is the history of the gradual retreat of the ice, with primitive man always following it northward.

The glaciers from the ice-clad apex of the pyramid were the main water-supply of Central Asia; and their disappearance, and the consequent drying up of large tracts of territory into desert, was the physical cause of the diminishing food-supply, which drove our earliest forefathers to wander farther and farther from the first home of the race in search of new hunting-grounds and pasture-lands. It was the combination of tropical heat and a good water-supply, with the

FIG. 27. RELIEF SKETCH MAP OF EURASIA

cooling winds from the snow-clad hills, which made possible the origin of human beings; and it was the struggle to obtain food, after the water-supply disappeared, that developed all the higher qualities in the dominant races of the world.

Central Asia was the birthplace of mankind. As the country became increasingly unfit for habitation the various nations spread out in all directions down toward the sea, and were for ever separated from one another by the gaunt deserts and barren mountains they had left behind. This towering wilderness was never recrossed by man, and all intercourse between the nations has taken place through the low-lying countries, and by way of the sea. This crumpling up of the continent into the Central Asian Tableland has been caused by great forces that are themselves due to the earth's crust contracting and pushing the land upward out of the Indian and Pacific Oceans.[1]

[1] You will find the best way to begin the study of any country is to ask yourself the question, "How am I to fold the map so as to show the main ranges of mountains in this country?" The ranges of mountains determine the watershed between the different rivers, and the river valleys largely determine the development of the country and its people.

CHAPTER VII

THE WATERFALL IN THE WOOD

THE waterfall in the wood is our shrine for nature-worship. When we are walking by ourselves we never pass it. We hear it calling before we see it. We pause beside it because it's alive. We revel in its company. We listen to its singing. We feel it has something to tell us. We can enjoy the music of an Italian love-song, though we do not know the meaning of its words. But if we know their meaning and feel their inspiration they thrill us. A waterfall is a glimpse into Nature's workshop. It tells us how the world was made. We worship, though we know it not. Here the secrets of the hidden structure of our earth come to the surface. The mystery of the streamlet's work is unravelled. We can see the meaning of its life. The sun and rain and Life are always trying to clothe our mother earth and make her beautiful. We want to see what is going on under the beautiful covering, to peer into the inside, and to watch the wheels go round. After we have worshipped at the waterfall, we wonder why it should be there.

An Irishman at Niagara Falls was asked, "Isn't it wonderful to see the water coming down like that?" "No," he said, "there's nothing to keep it up. It would be much more wonderful if it didn't come down." What keeps the water up? The rock. Why?

Because the river cannot cut its channel through it. If you would know the reason, look all around you!

All this country, except the mountains, is covered with a thick layer of boulder clay. It consists of the ground-up remains of rocks left by the glaciers, which for hundreds and hundreds of years ground their way across the whole country from the tops of the mountains, where they were continually fed by falls of snow, always grinding down, down, into the sea. It is called boulder clay because it is made up of clay, that is, rock ground down into the finest dust, and of boulders—large pieces of rocks which have been carried along inside the body of the glacier. These have had all their corners knocked off, and have been made round and smooth by being jumbled up among other rocks for hundreds of years. This boulder clay acts like a sponge and sucks in the rain, breathing it out in dry weather to the plants whose roots burrow themselves into it.

FIG. 28. A MINIATURE NIAGARA

Ths force of the swirl of the falling water dashing backward against the lower rocks and the chemical action of the spray in rotting the softer rocks are undermining the hard upper ledge, which will soon fall.

The river easily cuts its way through the boulder clay, washing out all the fine dust and leaving the stones, until it comes down to the solid rocks underneath. The stones are the river's tools with which it carves its way through the rocks, by turning them round and round and wearing away the rocks they are resting on. If the layers of hard rock are lying flat, or sloping downward toward the sea, then the river just flows over them; but if they are sloping upward it has to cut its channel through them, as their edges come up to the surface one after the other. The geologist walks along the river-banks, and, by carefully examining the different layers of rocks the river has cut through, he traces their history, and the history of the world.

You have seen a stone-work dam built across a river in order to store up the water, or raise its level to supply water to drive a water-wheel at a mill.

Every ridge of rock that crosses the track of a stream acts as a barrier or dam. It doesn't matter how soft the ground behind the ridge may be, the river cannot cut its way or carve out its channel any deeper into it than the level of the top of the dam. If you put a dam across a river channel the water has to wait till it has risen high enough behind the dam to be able to flow over it.

As water always stands at the same level, a dam only three or four feet high may raise the level of the river to that height for half a mile back. As long as the water is held up it is powerless. It is only when it is running with sufficient force to drag stones along with it that it can cut its way down and deepen its bed.

As the stream rolls its stones and sand along its sloping bed, when the stones reach the level part of the river behind the dam they must stop. The stones

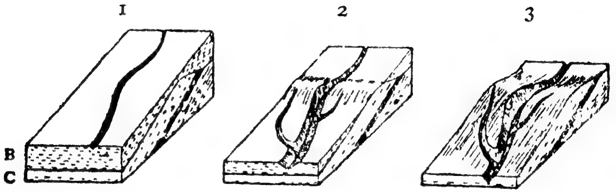


FIG. 29
(1) River flowing over soft rocks, B, (2) slowly cutting into hard rock, C, and then (3) carrying away soft rocks behind it.

coming down behind them are stopped in turn, and layer after layer is deposited till the channel of the river is filled up to the level of the top of the dam.

Once a stream succeeds in cutting the smallest

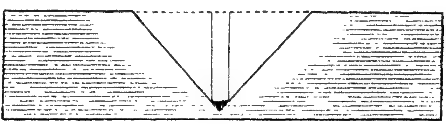


FIG. 30. DIAGRAM OF A VALLEY SHOWING HOW IT IS WIDENED BY THE BANKS CONTINUALLY FALLING INTO THE STREAM

channel for itself through the ridge of rock which bars its progress it very rapidly widens it into a deep gorge. It races through this gorge and carries with it all the stones and mud it receives from its higher waters, and will in the end lower the level of the whole country behind the ridge, which may be left standing as a great

wall of rock stretching across a broad valley through which the river flows.

If it had not been for these rocky barriers, which dam back the rivers at various places, all the soil and soft ground in the country would have been washed away into the sea long ago. The land might be com-

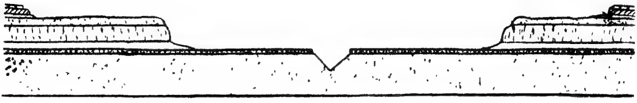


FIG. 31. CROSS-SECTION OF THE COLORADO CAÑON

pared to an iron grid with the spaces filled in with sand. Until the iron bars are worn through the sand cannot be washed away.

Once the river has cut its narrow channel through the rock it has little difficulty in widening it. It whirls from side to side, undermining the cliffs. These come tumbling down and supply it with a new mass of sharp grinding-tools.

A gorge like this is always V-shaped, with the narrowest part at the river's cutting edge, and gradually widening.

The height and shape of a waterfall depend on the nature of the ridge of rock. If it is a stratified rock like sandstone, or some lavas, which break away in cakes, the fall will be like a set of steps and stairs. If it is a thick, solid rock the fall will be like the water coming over a mill-dam. If there is a layer of hard rock on the top, with softer rocks underneath, which are easily decayed away, leaving the hard top ledge projecting, then

the fall comes over like water poured from a jug, as at Niagara.

The Niagara Falls are a striking example of the feebleness of unarmed water. The Falls could not continue to exist except for the fact that all the gravel

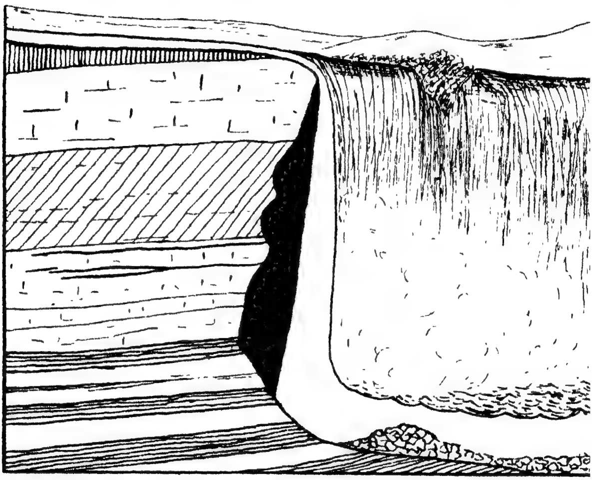


FIG. 32. SECTION OF NIAGARA FALLS

and sand brought down by the St Lawrence river system from its upper reaches is dropped to the bottom of the Great Lakes it passes through. In spite of its immense volume the Niagara river is soft and powerless, and cannot cut a gradually deepening channel for itself, as every other river does, and as it would do if it had not been deprived of all its cutting-tools. Flowing along the top of the rocks it cannot cut into, the river falls helplessly over their edge. Then it astonishes the

world by this display of its gigantic power, which is, in reality, a display of its weakness. When the river has tumbled over the edge of the hard layer of rock it swirls and splashes back against the softer rocks underneath it, one of which is a dried-up clay or 'shale,' which is easily softened and eaten out. The chemical action of the air and water on the softer rocks rots them away, and a cave is formed behind the waterfall, which grows deeper and deeper, until the overhanging ledge of limestone breaks off by its own weight, and crashes down into the pool at the foot of the fall. There, the stream of water is continually pouring down upon the broken pieces of hard limestone, turning them round and round on the rocks they are lying on, and constantly boring the pool deeper and deeper. As the limestone ledge is undermined and broken off at the rate of one or two feet every year, the Niagara river gradually eats backward, cutting a deep gorge through the rocks. When the river has cut through this sloping layer of limestone, it will soon tear its way through the soft rocks underneath and may lower the level of the whole of the Great Lakes, whose millions of tons of water are at present held up by this thin layer of limestone, hundreds of miles away.

CHAPTER VIII

THE WORK OF THE RIVERS

We read in the geography books that a river rises away up among the hill-tops as a tiny silver streamlet, and gradually grows from strength to strength by uniting with other streams which come to join it, as it flows on its way to its end in the ocean.

The geologist says a river begins at its mouth, and

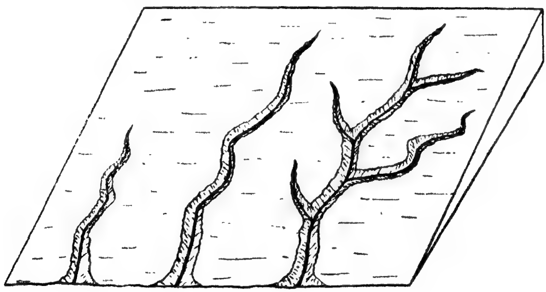


FIG. 33. GROWTH OF A RIVER

Geologists regard a river as beginning at its mouth, and gradually eating its way back into the land. It grows by sending out branches from each side, and draining the water from a larger and larger area of country and swallowing up smaller streams. A river is like a tree with its roots in the ocean growing upward into the land.

eats its way back into the country behind it by capturing the tributaries of other rivers, and stealing their territory and the rain which falls on it. This is true,

and it is far more important to know all about the mouth of a river than merely to know which is its longest tributary. The longest tributary indeed is seldom the most important, though it takes the river's name.

The mouth is the real thing, and the valley behind it.

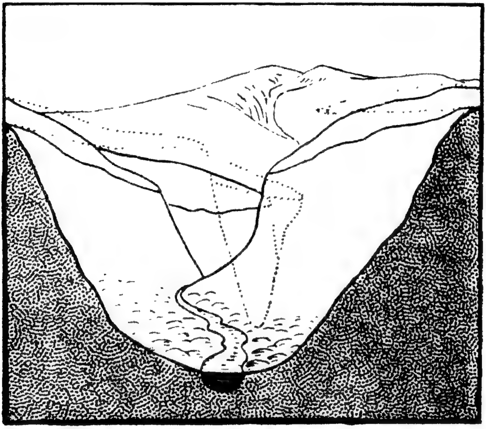


FIG. 34. RIVER GORGE (ORIGINALLY V-SHAPED, AS SHOWN BY DOTTED LINES) WIDENED BY GLACIAL ACTION INTO U-SHAPED VALLEY

Human history is the history of river valleys, because all civilized communities began in the valleys, and most wars have been fought for the possession of valleys. The first thing you want to know about any country is, "Where are its valleys, and what are they like?" When you know this you can guess its past history, and almost predict its future.

Most of our valleys have actually been cut out by

the streams which we see running down them to-day, though many of them were greatly widened by glaciers during the Ice Age. These valleys have grown wider and wider by the crumbling away of the rocks on each side, and by the work of the stream constantly sawing in at the foot of the cliffs and undermining them.

The valley was first cut out of the central tableland by a mountain torrent, then broadened by a glacier, and afterward deepened by the stream you see flowing through it now.

A river begins when one part of the ground happens to be lower than the rest. The rain runs into this hollow, and the force of the water running through it carries away some of the soil, making the hollow deeper. The rain, which would otherwise have gone straight on down the hillside, runs sideways into this hollow, and in its turn helps to deepen the bed of the little stream which has now been formed. As the hollow gets deeper the stones and broken bits of the rock slip in from the sides, which have been undermined by the little stream. These stones fall into the stream itself, and are carried away by it.

If you look along the floor of the valley you will see a heap of broken pieces of rock at every place where one of these rills joins the stream. These fragments have been carried down the hillside by the water rushing between the banks of the narrow gully. Once free of the little channel, the water can escape into the main stream, without the trouble of carrying the stones along with it; so it leaves them piled in a heap.

When the snow melts in the spring-time there is a

tremendous quantity of water that wants to rush down from the hills into the sea. This causes the stream to swell and rise several feet higher in the valley, and to carry away with it all the piles of stones which have been brought down to its side by the little mountain torrents.

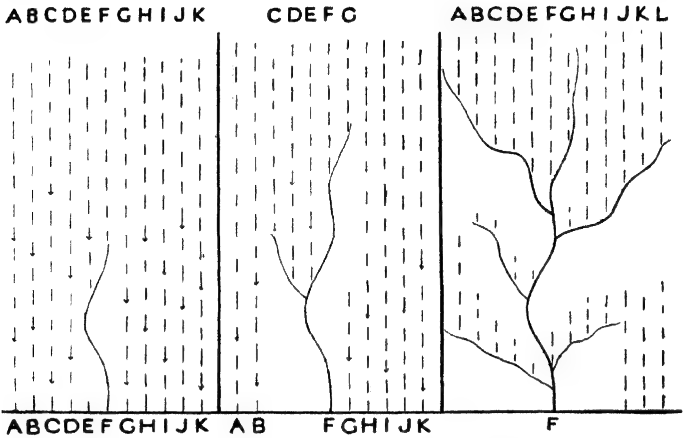


FIG. 35. BEGINNING OF A RIVER

On an even slope the rain-water would run straight down in a number of small streamlets (A to K). Suppose a boulder or some other obstruction causes streamlet F to swerve from its course far enough for it to intercept the waters of E. The united waters of E and F would cut out a much deeper channel than any other of the single streamlets. Now let G be diverted into F, and the combined E, F, G will cut a channel so deep that the other streamlets D, C, B, A, etc., will drain into it sideways, and soon the one river will drain the whole region.

But it may be asked how it is that stones, which do not float, but always sink to the bottom of the water, are carried away?

The stones do not actually float, but they are carried along the bottom of the river by the force of the water, and rolled over and over in its bed on the way down to

the sea. All the stones in the world were once rough pieces broken off the solid rock, and you can always tell whether a stone has travelled far, by seeing whether its edges are rough and sharp, or whether they have been ground away and smoothed by the action of water.

In a river valley there are beds of gravel on each side of the stream. High up on its banks quite large stones have been left by the river when it was in flood. If you look at one of them closely you will notice that the edges are all rough, and at once realize that it is a piece split off a big rock. If, on the other hand, you look at the small pebbles in the bed of the stream you will see how beautifully rounded they are.

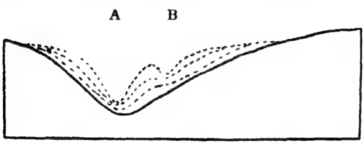


FIG. 36. CROSS-SECTION OF A RIVER VALLEY

Streamlets A and B are flowing parallel to one another down the slope. A grows larger, and gradually the ridge between it and B is eaten away (as shown by dotted lines), and the two gullies form one valley.

The work of the river is to roll the stones down to the sea. It turns them over sideways, just as you would roll over a big stone that was too heavy for you to lift. If a stone happens to get turned lengthways to the stream it is allowed to lie that way, because the current cannot get a grip of it to turn it over. The stones in the bed of a river are not just left lying anyhow. You will always find them lying with their longest diameter along the channel, and with their thinnest edge pointing up the stream, like a ship at anchor, which always rides with its bow facing the tide.

These details seem of no consequence, but if a geologist comes across a bank of gravel thousands of years after the river which laid it down has disappeared they would enable him to say: "These stones were placed here by a stream which flowed along their longest diameters, and from the direction to which their thinnest edges slope and point."

By these simple indications geologists in America were able to calculate the position of the bed of a river which had been buried under a mass of volcanic rock that had poured up out of the earth thousands of years ago. Miners drove a tunnel into the side of the mountain to the place where they thought they would find the bed of the old river. They found the old river channel and mined out all the gravel, which was very rich in gold-dust and small nuggets. Then they washed out the gold and made a large fortune.

River piracy is a most fascinating study. Whenever you come across a valley with no river in it ask yourself, "Where is the river which carved out this valley?" and you may find out some very interesting history. The Clyde, for instance, was once a tributary of the river Forth, which flowed out of Loch Lomond, and the seven tributaries of the Yorkshire Ouse, the Swale, Ure, Nidd, Wharfe, Aire, Calder, and Don, were once independent rivers, rising on the slopes of the Pennine Chain and flowing eastward to the sea, like the Tees and the Tyne to the north of them.[1]

The Humber, eating its way in from the sea, carved

[1] See diagram on p. 101.

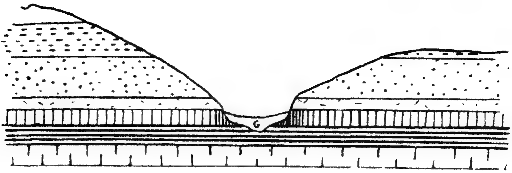


FIG. 37

The river is flowing through a bed of gravel, G, which contains gold nuggets.

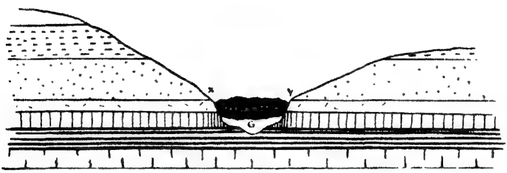


FIG. 38

A stream of lava rolls into and fills up the valley and the bed of the river. The tributaries of the old river coming from the hills on the left flow along the edge of the cake of lava and unite to form the new river X. Those coming from the right form the new river Y.

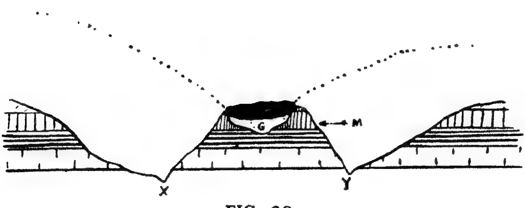


FIG. 39

The new rivers X and Y cut valleys for themselves into the sides of the old hills, which they undermine and wash away. The lava, being much harder, preserves the gravel and other soft rocks under it. The old river gravel, G, is now lying on the top of a hill, and geologists, having calculated where it ought to be found inside the hill, drive in the mine M and extract the gold.

out the valley now occupied by the Aire. It happened to be working in the soft Triassic rocks, which come to the surface between its source and the sea (Fig. 40). It cut out its channel more quickly than its neighbour the Calder, which had harder rocks to contend with, and one of its tributaries cut its way southward and beheaded the Calder and stole its water.

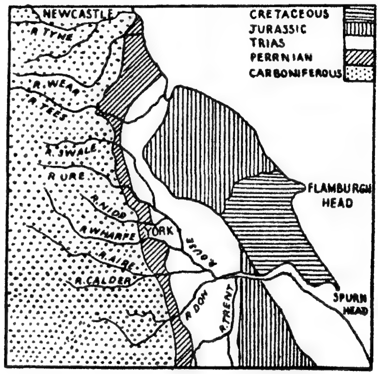


FIG. 40. HOW THE HUMBER MADE YORKSHIRE

Having now got twice the quantity of water to work with, the Humber carved out and deepened its valley still more quickly than any of its neighbours; and all its tributaries, which were now flowing into a much deeper river, had a steeper slope to run down, and ran faster, and cut out their own little valleys far more rapidly than the tributaries of the older rivers.

One of the tributaries of the 'Humber-Calder,' now called the Ouse, cut its way northward and beheaded the Wharfe and captured its water. This new 'Humber-Calder-Wharfe' combination with its greatly increased water-power vigorously excavated their separate valleys, and quickened the running of all their tributaries. Soon the Nidd, the Ure, and the Swale

were beheaded, and all their drainage areas captured. Then this York Amalgamated Earth-Excavating Company scooped out the Vale of York, and left a ridge of hills between it and the sea, which guarded its inhabitants from invasion.

All this time the Humber was not only making drains, it was making history. It was creating Yorkshire, for Yorkshire is just the territory drained by the Humber and its tributaries. This system of river valleys all communicating with one another gave unity to Yorkshire, and made it a centre of civilization, and its people have always worked together as a large community, and exercised a great influence on the history of England.

The Y.A.E.E. Company not only organized the county as a self-contained community when agriculture was the chief industry, but it founded modern woollen manufacture by providing the water-power to drive the first mills, and it discovered the coal and iron and grinding-stones for steel by cutting into the land and exposing the mineral seams.

In the Ice Age, or just before it, Scotland stood a thousand feet higher than it does now. The old channel of the Forth has been discovered five hundred feet below the sea which now covers its valley and forms the Firth of Forth. The windings of this ancient river, buried underground for thousands of years, are now being explored by miners digging out the coal under the sea. Without any warning, as they are working out the seam of coal, the miners strike a solid face of boulder clay and know that they have come across another bend

of that old river. They drive the tunnel through the boulder clay till they come again to the same seam of coal in the opposite bank, and then go on working it out. The buried channels of the Old Forth, and of the river Devon, which is one of its principal tributaries, have now been mapped out from information supplied by the coal-workings and bores put down to locate the

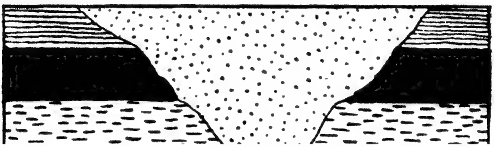


FIG. 41. BOULDER CLAY FILLING VALLEY OF OLD FORTH RIVER

coal. To-day we can trace the wanderings of this prehistoric stream as it slowly carved its way down through the various beds of sandstone, and shale, and limestone, and iron and coal, which make up the Carboniferous series. You might call it a fossil river composed of boulder clay. The course of the Old Forth can be traced along the bottom of the North Sea toward the point where it became a tributary of the prehistoric Rhine, which flowed through the North Sea Plain, then 400 feet above sea-level (Fig. 19).

The secret of the Tay Bridge tragedy lay in the buried valley of the prehistoric river Tay. Up till the fourteenth pier from the Dundee side the foundations were on solid rock; then, contrary to the engineers' calculations, the rock disappeared. They were building on the top of the prehistoric river

channel, but they never knew it. A lighter kind of foundation for the piers was used. The test of the great storm and a heavy train came. The bridge fell.

Scientists had often warned London of the danger of a flood like that of January 1928, which was caused by a high tide coming up the river at a time when it was flooded by heavy rains.

Within historic times Westminster Abbey stood on an island in a marsh, and the waters of the Thames came right up to the Strand, which was the actual shore of the river.

The wide expanses of mud and swamp on both sides of the river were unsightly, and wasteful of good building land, but they were most useful safety-valves against floods and high tides. While London was building over three-quarters of Old Father Thames' bed she ought to have remembered that he was a mighty giant who would want to move some day, and that it might need great strength to hold him down in the narrow channel left for him.

The more agricultural land is drained, the quicker the rain runs off it into the river. It runs off roofs and streets quicker still. This increases the danger of sudden flooding. The London embankments and wharfs and warehouse-walls on both sides of the river have converted it into a long, narrow bottle-neck through which the water can pass only slowly. It dams back the flood-water coming down the river and the tide-water coming up, and raises the levels of both.

CHAPTER IX

THE EMPIRE OF LIFE

As we ascend the river the valley grows narrower and narrower, till the hills slope down into the water. At the corner here we have a good example of one way in which a stream widens its valley. You will notice that the river originally flowed round in a great curve, and cut its way into the base of the hill on our right. It continued to undermine the hillside till it caused a land-slip; all the loose earth and rocks lying on the side of the hill above the bank into which the river was cutting slipped down into the river and filled up its channel to such an extent that the stream was forced to flow over against the opposite bank, which it is now in its turn undermining. There are no trees on the side of the hill where the landslips took place, because the soil in which they should have grown has fallen down into the river, and left nothing but the bare rock. The low waterfalls and rapids (see Fig. 42) are caused by a layer of hard rock which comes to the surface there. It dams back the river and prevents it carrying away the mass of stones and earth which have fallen into it from the hillside.

At the foot of the valley there is a large flat space with room enough for a field on each side of the stream. All the soil here has been brought down by the river, and is called alluvial soil. As the valley broadens out

the water spreads over the surface, and of course becomes shallow. It is therefore able to carry only small stones and grains of sand with it, and, besides, it flows much more slowly. The slower the current, the less power it has to roll the stones along with it, so they drop

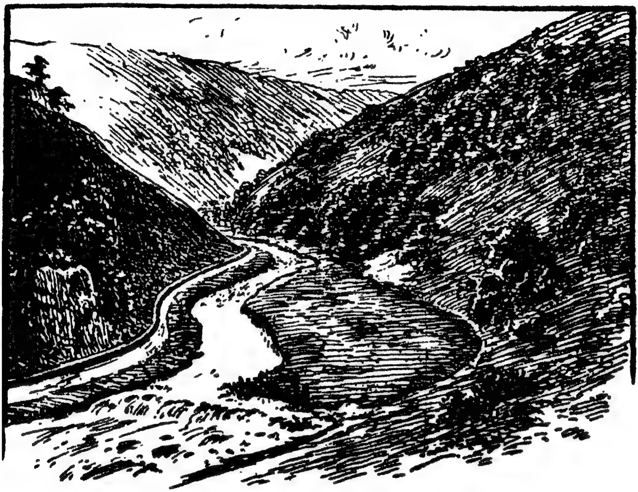


FIG. 42. A SMALL RIVER VALLEY

out and fall to the bottom. Then the mud falls into the spaces between the stones, and is held there, and fertile soil begins to be formed.

The common idea of soil is that it is just broken-up rock. In one sense this is right, but in another it is very far wrong.

There is all the difference in the world between a cubic inch of broken rock and a cubic inch of soil. In

passing from one to the other you have crossed a gulf of millions of years. You have left an old world behind you, and entered an entirely new one. Everything that can be said about an inch of rock could be written on one sheet of paper. You state its weight, its colour, its chemical composition, and microscopic structure, and its probable relations to other rocks. But that is the end of the story, and you must stop. A cubic inch of soil is a world in itself. Millions of animals, which we call bacteria, are living in it. It is their nursery, their graveyard, their home, their factory, and their battle-field. Before you finish their story you will have written the whole history of the universe.

Three tiny grass blades are sprouting there from a crack in the rock. That is the battle-flag of the Empire of Life. Let us pull up a tuft of grass and see what it is doing on the stony hillside. Its roots go branching down between the stones and prevent the grains of sand which lodge there being washed out again by the rain.

This network formed of roots and grains of rock retains the water like a sponge. The imprisoned water works away at the grains of sand, breaking them up still further, and dissolving out certain substances. The plant wants these substances for food.

Every root is a little pipe through which the plant sucks up the water, which has some of the dissolved rock in it. The plant digests this solution, breathes out the water, and builds the mineral substances into its own body, along with other food which it takes out of the air. So the plant grows.

The plant has the power of making vegetable acids; these help the water to dissolve the rock still faster, and make more food for the plant to eat. Then animals come to eat the plant, and they in turn leave manure. The manure contains animal acids which also dissolve the rock. When the leaves or stems of the plant die they are eaten by earthworms. These worms are always working away, tunnelling through the broken bits of rock, and turning them over and over, so that the water, the air, the sun's heat, the frost, the vegetable acids, and the animal acids can attack the grains of rock and break them down smaller and smaller. Then countless armies of bacteria set to work and prepare the soil for other plants to grow in it.

Suppose we try to put it in the form of the familiar story, *The House that Jack Built*. Let us start:

> This is the rock that the world was made of.
> This is the sun that cracked the rock that the world was made of.
> This is the water that lay in the crack and dissolved the rock that the world was made of.
> This is the seed that fell into the crack, and grew into the plant, that sucked up the water, that dissolved the rock that the world was made of.
> This is the animal that ate the plant, and so on for ever and ever!

And in a sense the very rocks are growing too. While these rocks we see are being slowly broken up and carried away, other rocks are being formed underneath the sea, out of the sand which the rivers are always carrying down to it. These new rocks are building up into themselves not only the remains of older rocks, but the remains of animals and plants which have been

brought down by the rivers along with the sand and mud.

Did you ever think of a mountain owing its preservation to blades of grass? You look up at the old weather-beaten heights, and say they are worth next to nothing, because the grass is so scanty that it is a hard day's work for a sheep to find its dinner on ten acres.

I see on that bare hillside the fighting-line in the great battle between the army of life and the forces of destruction. Ages ago the flying scouts of the Empire of Living Things, the advance-guard of the 'civilization' we depend on—in the form of tiny grass-seeds borne on the wind—settled on the edge of the brook there, and conquered an inch of the desolate hillside. Spreading their rootlets—like barbed-wire entanglements—they caught the little grains of broken rock brought down by the rain, held them prisoners, and fed on them. Next year these grass-plants sent forth their regiments of seeds to fly round the rocky ground and try to discover a crack to rest and grow in.

Inch by inch the silent army pushed forward its entrenchments over the enemy's country, hoisting a little green flag as each grain of soil was added to the Empire of Life. Our soldiers and statesmen glory in "painting the map of the world red," but the real constructive work of civilization lies in clothing the mountains and making the desert green.

Look up and down the higher part of this valley now, and see how quickly the gullies are cutting their way back into the mountain wherever the grass has once been removed. It is an almost perfect shield against

sun and frost and heavy rain. All along the ridge of the hill there grass is contesting each inch of the ground on the mountain-top, and saying to the forces of destruction, "Hitherto shalt thou come, but no further."

I have often been astonished when cutting the turf off the top of a rock to look for glacial markings to see how marvellously the scratchings have been preserved for so many thousands of years.

The grass is not only the preserver of mountains, but the conqueror of the sea.

All round the margin of a sandy bay you can watch the grass-plants working day and night, sending forth swarms of seeds to invade the territory of their enemy the sea whenever the tide goes out. Every wind that blows the sand inland bears some of the grass-seeds with it, and wherever the sand-grains fall the grass-seeds attempt to annex them for the Empire of Life.

The drifting sands, streaming across the country, are caught among the tough stalks of the bent-grass, and, as every successive wind-storm brings its layer of sand, new grass blades push their way up through it and bind it down to the land. All the sandhills which surround our coast have been caught by the grass and anchored down layer by layer. Miles of land have thus been raised above the level of the sea and added to the area of our country.

Skeletons of whales (actual bones, not fossils) have been found in Cambridgeshire, which must have lain under the sea not so very long ago.

The work of the rivers and of the sea is well illustrated in the Report of the Royal Commission on Coast

Erosion. It was found that during thirty-five years about 6640 acres have been lost to the United Kingdom, while over 48,000 acres have been added. The gains are almost entirely in the tidal estuaries, which are being continuously filled up by the rivers with sand and gravel brought down from the land. When you remember that every square foot of the 48,000 acres represents the top of a long, sloping pile of sand which has been built up from the sea-bottom, and that by far the greater part of the material brought down by the rivers is carried right away into deep water, you will realize how many millions of tons of soil must have been robbed from the land during this short period.

The water-plants in the Fen Country are continuously raising the level of the land by anchoring and binding the mud brought down by the rivers, as well as the sand blown inland by the winds. This, however, chokes up the watercourses, dams back the rivers, and destroys the drainage of the higher lands.

While, as patriots, we rejoice in the 48,000 acres added to our native country, practical farmers bitterly complain that over 1,000,000 acres of the best agricultural land have been rendered waterlogged and useless by the silting up of the lower parts of the rivers and the consequent upsetting of the natural drainage system. The farmers on the upper reaches deepen their channels to get rid of the water, and they are always at war with those lower down who have to receive this water on their lands. The two maps in Figs. 43 and 44 show the extent to which the Wash has been filled up since the Roman period in England.

The Roman legislation to provide a remedy was not very successful. Disaster overtook Prince Seithenyn ap Seithenyn, the Fen Drainage Commissioner to King Gwythno in the seventh century. Henry VIII put things right for a time with his drains and pumps and dredges. Successive Dukes of Bedford spent over £1,000,000 of their own money on drainage schemes,

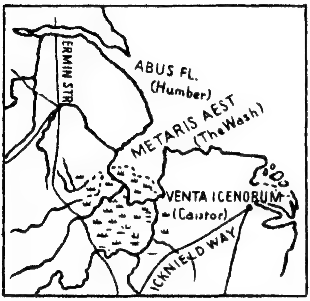


FIG. 43. THE WASH IN ROMAN TIMES

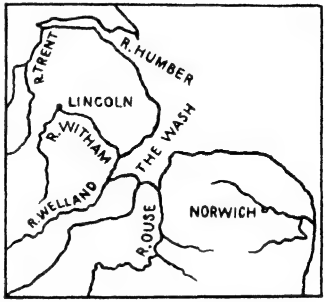


FIG. 44. THE WASH TO-DAY

and in March 1927 a Royal Commission with Lord Bledisloe as Chairman was appointed to go thoroughly into the matter, and try to solve a problem which has baffled English engineers and legislators for two thousand years.

A river is always carrying down sand and gravel to the sea. When the tide comes in it throws the sand and gravel back into the mouth of the river and forms a bank or bar across the mouth. When the current of the river is strong it cuts a channel for itself through the bank, or it turns to one side or the other in order to get past the end of the bank. Natural harbours are formed

when the river turns sideways and flows past one end of the bank, and the other end is joined to the land and that side of the river mouth is completely filled up.

The 'harbour bar' is the name given to this bank of sand thrown across the mouth of the river. It is always a difficult and dangerous thing for the ships to get over or past these banks of sand, and much of the romance and tragedy of the sea is associated with the harbour bar. This bank of gravel stretching across the mouth of the river catches the sand and mud coming down with the water, and tends to dam up the river, so that it flows much more slowly. The slower it flows, the less mud and sand it can carry with it, and the rest is dropped down and fills up the river mouth. When a flood comes the river cuts a new channel for itself through the harbour bar. This new river mouth is again barred in the same way, and so the river goes on

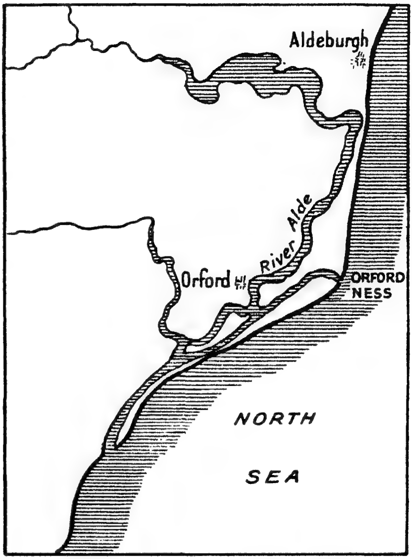


FIG. 45. THE COURSE OF THE RIVER ALDE

building one bar after another farther and farther out to sea. As the river water filters through bar after bar it leaves its sand and mud behind it, and so great deltas are built up, yard after yard.

On the coast of Suffolk, for instance, there is a strong drift to the south-west. The river Alde used to enter the sea at Aldeburgh, eight miles to the north of its present mouth, but the south-west drift of the tides always threw back the gravel it brought down into a bank across its mouth. The Alde turned to the south to get round the bank, but every tide threw back more gravel on to the end of the bank, which is now eight miles long and still growing longer. This bank dams up the river and has formed the lower part of it into a lake, which is filling up and becoming a swamp.

In the spring of 1927 the great city of New Orleans was threatened with destruction by the floods of the Mississippi. The Mississippi with its tributaries drains the whole of the central part of North America, and has been carrying down 406,250,000 tons of mud every year into the Gulf of Mexico for hundreds of thousands of years, and building up a great delta. If the river had been left alone, when the floods came it would have overflowed its banks and deposited its mud over miles of country, and raised the height of its delta. Man interfered. New Orleans became a great seaport, and the swampy lands on both sides of the river became very valuable for growing cotton. Artificial banks[1] fifty feet high were built along both sides of the river for hundreds of miles to prevent it from overflowing its

[1] Called levees.

banks and flooding the country. At flood-time every few years the artificial banks were raised higher. The muddy water could not escape. The mud sank to the bottom and raised the level of the river-bottom, and then the artificial banks had to be raised again. After a hundred years of this filling up of the river-bed, and heightening of the embankments, the mighty river was flowing round the city fifty feet higher up than the houses. Then news came that tremendous floods were coming down the river, and that its artificial banks could not possibly withstand the power of the water. After weeks of anxiety the artificial banks some miles below New Orleans were blown up with dynamite, the country for hundreds of miles round was flooded, millions of pounds' worth of damage was done to the farms and cotton plantations, for days the water was running level with the top of the embankments and thousands of men were piling on sandbags wherever the river threatened to burst through, but the great city was saved.[1] Now the United States Government engineers have prepared plans for the control of the river in future, at a cost of £60,000,000 and including a 'spill-way' above New Orleans to allow future floods to flow past it to the sea. London faces a similar problem owing to the continual encroachments on the old bed of the river. Narrowing the channel holds back the water and increases the deposit of mud. If the Thames embankments had been fifty feet higher, and the flood had been running level with their tops for a month, London would have sympathized with New Orleans.

[1] See page 39.

CHAPTER X

THE WORK OF THE SEA

THE sea has been compared to a great horizontal steam-saw constantly cutting into the land all round the coast, sawing off the cliffs and small hills, and leaving a wide, flat plain, over which it rolls for ever.

The pieces of rock broken off the cliffs lie at their foot, for the sea to use them as hammers with which to strike the remaining rocks, till a fresh piece of the cliff has been undermined and falls down in its turn. Every piece of rock that drops into the sea becomes a battering-ram continually being swung by the waves against the parent cliff.

The sea in a storm can lift a block of stone weighing twenty tons to a height of thirty feet, and hurl it against the face of the cliff with tremendous force. The actual mechanical power of the sea-waves is enormous. The average pressure of the Atlantic waves on the western coasts of Britain is estimated at 600 lb. to the square foot in summer, and 2000 lb. in winter. During a storm the wave-pressure of the North Sea at Dunbar was found to be $3\frac{1}{2}$ tons per square foot.

In the cliffs are great cracks running inland. The waves are constantly dashing into these cracks, widening them into small creeks. The stones and broken rocks which fall from the cliffs can never get out of the creeks, but are kept continually rolling backward and

forward, always grinding away at the base of the cliffs. This picture shows where the cracks have become wider and wider till the whole cliff has been worn away and only narrow pillars of rock are left to show where the cliff stood not so long ago.

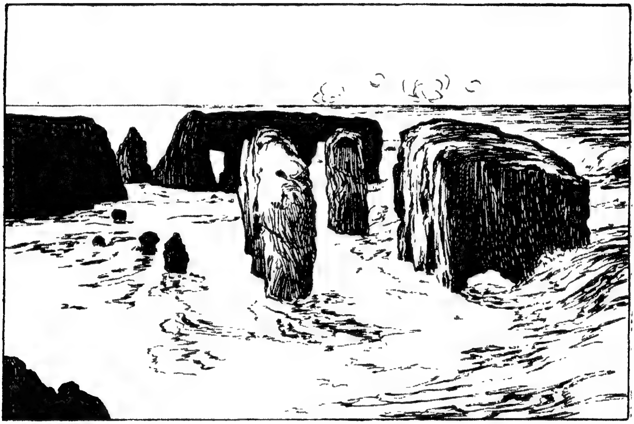


FIG. 46. 'STACKS,' HARD PARTS OF THE CLIFFS LEFT STANDING AFTER THE SOFTER PARTS HAVE BEEN WASHED AWAY

In some places banks of shingle, formed by the breaking down of the cliffs, have barred back the sea, but there is very little evidence to prove that land once taken away by the sea is ever restored. The Goodwin Sands, so dreaded by sailors, were still dry land in the eleventh century.

Fig. 47 gives a sketch of an interesting rock-pillar which the Berwickshire fishermen called Standalane. At first sight you would say it was impossible that this

fantastically shaped monument could be the work of the waves, but if you compare the strata of the sandstone it is composed of with the strata of the adjoining cliff you will see that they are identical. It is the same waves that have cut the archway through the cliff, and in a few years the roof of the arch will fall, leaving quite as fantastic a stack as old Standalane himself; this pillar in its turn will be undermined by the sea, into which it will finally topple over.

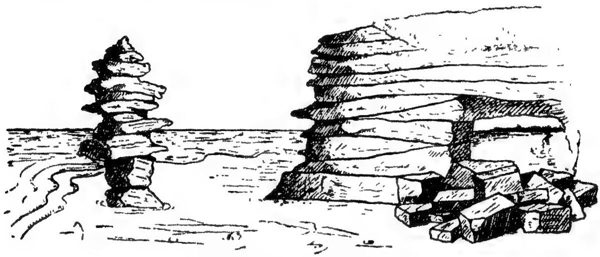


FIG. 47. STANDALANE

In striking contrast to the rock-breaking might and fury of the sea is its helplessness without its teeth. Deprived of its sand and gravel, the sea cannot even scratch the rocks. The bosom of the deep is the quietest and most restful place imaginable. It is the great world-wide museum in which nearly all our geological specimens have been preserved. Immediately you get below the shallow surface layer, which is constantly disturbed by the winds and the tides, you reach the still depths of everlasting sleep. The restlessness of the sea is all on its surface. A short way down is constant peace and eternal repose, in which the

most fragile organisms can rest undisturbed for millions of years, until each of their separate particles is replaced by a particle of stone, and they become fossils, the monuments of a long-passed world, of which every other trace has vanished.

The sea is not the destroyer, but the rest-giver and re-creator of the whole world. It is the rain that crumbles the rocks and breaks down the mountains.

CHAPTER XI

HOW THE MOUNTAINS WERE MADE

NONE of the mountains have sprung up at random. All the ranges are connected, being parts of great systems of earth-folding—gigantic wrinkles in the earth's skin caused by its contracting in order to fit itself on to its constantly cooling core. (See map of Eurasia, Fig. 27.)

It may be asked how we can prove that the mountain ranges have actually been made by folding. The answer is that nearly all the rocks in the world have been laid down in great flat layers, one above the other. The materials of which the successive layers are composed have been brought down by rivers and spread out over the floor of an ocean, each layer in its turn being buried under the succeeding one.

We can trace the same succession of rocks, in the same order, stretching across the continents for thousands of miles.

When we come to the slope of the mountains we find that the series of rocks we are following does not stop short, but continues right on, rising with the rise of the slope. On the top of the mountain we find that our rocks *A*, *B*, *C*, and *D* are still lying under one another in the same order, and that the series continues unbroken down the opposite slope. (See Fig. 50.)

It is quite clear, therefore, that these layers at one

time were all lying flat one above another, and that they have been folded up together into a ridge, which we now call a range of mountains.

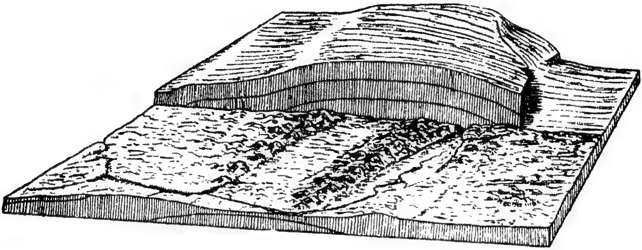


FIG. 48. THE UINTA FOLD IN THE BACKGROUND IS SUPPOSED TO HAVE REMAINED UNERODED, WHILE THE FOREGROUND SHOWS THE UINTA MOUNTAINS AS THEY EXIST NOW

Mountains are formed by upheavals and crinklings of the earth's crust—like wrinkles on the skin of an apple which has shrunk as it dried.

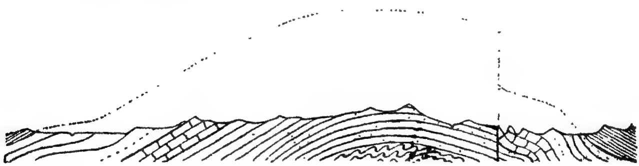


FIG. 49. DIAGRAM OF THE ACTUAL STRATA, BY CONTINUING THE DIRECTION OF WHICH IT WAS POSSIBLE TO CONSTRUCT THE RELIEF MODEL OF THE UINTA RANGE UPFOLDING SHOWN ABOVE

You may say that I talk about folding up Europe and Asia as if they were a sheet of newspaper. It would take an enormous force, you think, to drag the two sides of a continent toward one another, and push a range of mountains right up into the air.

If you had a cloth lying on the table, it would not take an enormous force to move one edge of it toward the other sufficiently far to make the cloth rise above the table the hundredth part of an inch.

If you draw your hand slowly but firmly along the tablecloth on the table, the cloth in front of your hand will wrinkle up into folds, because you have now got a foot and an inch of the cloth lying on one foot of table, and it cannot lie flat because it is too long for the part of the table it is lying on, and so wrinkles are caused.

The skin of the earth has become too big for it, because the inside core has cooled, and therefore grown smaller. The crust of the earth wrinkles up into mountains because the contracting core draws the two sides of a continent closer together.

The height of the wrinkles of the tablecloth is, of course, a hundred times greater in proportion than the height of the mountains above the sea-level.

It is quite easy to see how and why the wrinkles have been formed in the tablecloth, because it is lying open before you, and it is very evidently one continuous layer of green material, but the wrinkled rocks in the earth's crust are all covered up, and only appear in disconnected patches.

Pour some sand on to the wrinkled tablecloth till it is just deep enough to fill the hollows between the ridges, and level it by drawing the edge of a book across it. You have now a white patch of sand with the ridges appearing as green lines across it, and if you looked only at the surface of the sand you would have some difficulty in proving that the green lines were parts of

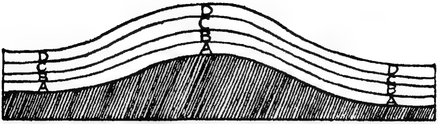


FIG. 50. MOUNTAIN-FOLDING

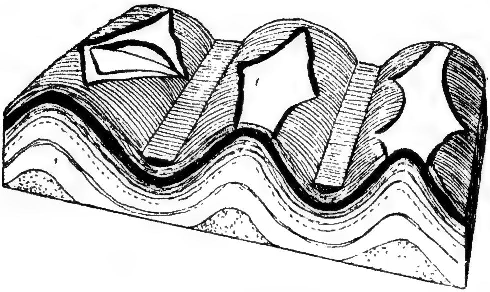


FIG. 51. JURA ALPS, SHOWING FOLDING OF ORIGINAL STRATA, EROSION OF MOUNTAIN-TOPS, AND FILLING UP OF VALLEYS BY THE PRODUCTS OF EROSION OF MOUNTAIN-TOPS

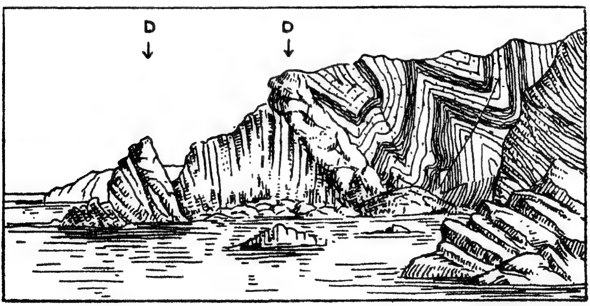


FIG. 52. CONTORTED SILURIAN STRATA HALF A MILE NORTH OF BURNMOUTH, BERWICKSHIRE (GEOLOGICAL SURVEY)

D, 'dykes' formed by molten rock which has been forced up from beneath into cracks in the overlying rocks caused by their being crumpled together.

one continuous sheet. If you scraped away the sand from the right-hand side of a ridge you would find the green cloth sloping down or 'dipping' beneath the sand, and if you scraped it away from the left-hand side of the next ridge you would find the cloth rising up

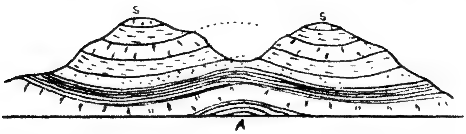


FIG. 53. HILLS ERODED OUT OF FOLDED STRATA
A, anticline. S, S, synclines.

from under the sand again, and you would be justified in assuming that there was one continuous layer of cloth stretching beneath the sand, and alternately rising to the surface and falling beneath it again.

The layers of rock at the top of the ridges are said to form an 'anticline' (from two Greek words meaning '*leaning against* one another'), and the layers of rock at the bottom of the hollows are said to form a 'syncline' (meaning '*leaning toward* one another').

FIG. 54. ERODED ANTICLINE

Look again at the sand on the wrinkled tablecloth. Suppose we were to damp it, press it until it became solid, and then remove a layer an inch thick from the top of it, cutting right through the folds of the cloth. Instead of ridges, we should then find separate cut edges of the cloth at the surface of the sand. If we scraped away a little of the sand from the edges of the

cloth we should find the angles at which they dipped and rose, and after a little calculation we should be able to reconstruct the foldings and to say that all these cut

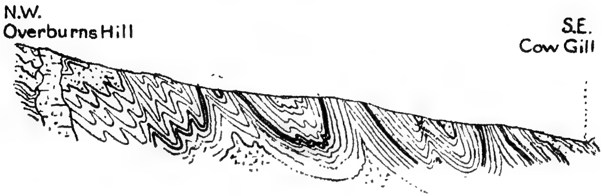


FIG. 55. SECTION IN COW GILL, BASIN OF CULTER WATER, LANARKSHIRE (GEOLOGICAL SURVEY)

edges formed one continuous sheet, and were once joined above the surface by ridges that have been worn away.

By the same kind of calculations geologists can reconstruct the foldings of the rocks *o*, *o* (Fig. 56), the tops of which were completely removed thousands of years ago, and also say how and where these strata are connected underground, as indicated by the dotted lines.

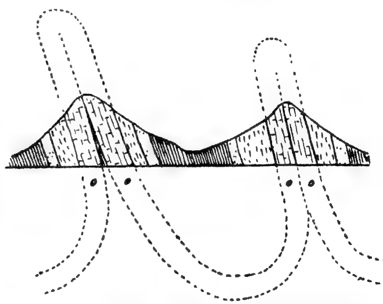


FIG. 56. RECONSTRUCTED FOLDINGS

If we find a succession of strata dipping, as in this diagram, we have no hesitation in saying that they formed part of an anticline, the top of which has been worn away, and whose height we could determine by

continuing the lines of the different strata until they met.

Here is a section through Mont Blanc made by observing the angles at which the various strata dip below the surface and rise out of it again.

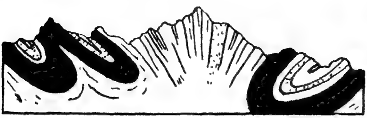


FIG. 57. SECTION THROUGH MONT BLANC ('FAN STRUCTURE')

By means of series of these sections geologists have been able not only to prove beyond all doubt that the Alps have been formed by a crumpling up of the surface of Europe in comparatively recent times, but also to state exactly at what period in the earth's history each particular wrinkle in its crust was formed. The Alps are the youngest mountains in the world, and I have far more respect for the hills in Wales and Scotland, for they are millions and millions of years older than the Alps.

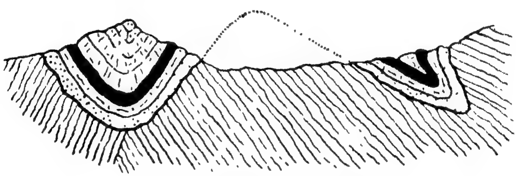


FIG. 58. ALPINE STRUCTURE

Fix one end of a sheet of paper to the table by laying a book on it. Press the other end toward it. The sheet will bulge up in the middle. That is a tableland.

You will learn more about mountain-folding by working with a sheet of paper for ten minutes than by reading books for hours. A thrust of half an inch is quite sufficient. Turn the sheet of paper with its raised edge toward you. Now run your finger very gently up and down the bulging paper. Notice how you cause a little wave of elevation to run up and down in front of your finger; and how you get almost every variety of gentle and steep folding.

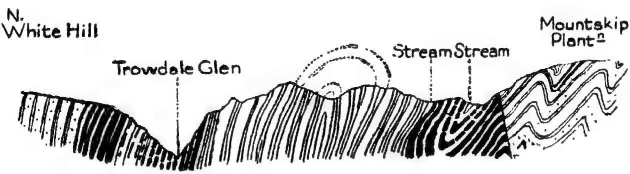


FIG. 59. SECTION ACROSS TROWDALE GLEN, WATER OF URR, STEWARTRY OF KIRKCUDBRIGHT (LENGTH ½ MILE) (GEOLOGICAL SURVEY)

When the inside of the earth is cooling and contracting under its hard, inelastic outer crust the two opposite sides of a continent are being dragged closer together. This causes the surface to bulge up just like the sheet of paper. The slight pressure of your finger, which threw the bulge into all manner of waving folds, represents the weight of the rocks of which the bulging skin of the earth is built up. This immense weight of miles of overlying strata is always throwing the crust downward, at the same time that the contracting earth is dragging its ends together.

Bend a cigarette slightly and watch how the paper wrinkles up on the inside of the bend.

Take a sheet of paper and roll it tightly into a solid rod. Bend the two ends of the paper rod together. Never mind if some of the outside folds burst at the bend. Now straighten the rod and look at it. The layers of paper that were on the inside of the bend are all squeezed and crumpled together, while the outside layers are drawn out, and some of them are torn asunder.

Unroll the paper and look at it. The extension and compression is repeated again and again. Each crumpling is the counterpart of the following one. The distortion of the layers gets less as you approach the centre of the rod, because the centre layers were bent through a shorter distance than the outside ones.

Every part of the earth's crust is made up of layers, like the rod of paper. When any folding takes place the outside layers are stretched out and torn asunder, and the inside layers are all crushed together. The layers of rock which make up the earth's crust are much more brittle than layers of paper, and often break right through.

Take three matches, or, better still, a number of thin strips of wood, and place them one above the other. Bend them as you bent the rod of paper, and watch what happens. Now remember that the layers of the earth's crust, which bend and crumple and stretch and break when they are folded in the same way, form the outside skin of a globe of liquid, which is under great pressure and determined to escape through every possible outlet. Sometimes the crust of the earth cracks right through at the top of the fold, and you have a great outpouring of lava, and a whole chain of

volcanoes—like the great world ridges which form the Andes and Rocky Mountains.

Bend another three matches. Watch how they are displaced with regard to one another. The top match breaks, the second half breaks, and the inside one is crumpled. See how they have slipped over one another, and notice especially the empty spaces that are left between them. Now, if a liquid under great pressure were trying to break through this skin you can imagine how it would burst right up through a broken layer, fill all the empty spaces between two bent layers that had been forced out of position, flow along until it found a crack or a weak place in an overlying layer, and finally escape to the surface. This is the story of the injected igneous rocks as traced by geologists.

The rocks inside the part of the earth's crust which is being bent upward into mountains by the tremendous force of the world's contraction pushing the opposite sides of a continent together are greatly altered by the terrible ordeal they have gone through. They have been subjected not only to unthinkably great pressure, but to terrific heat. The texture of the rocks is changed. All are compressed and hardened, some are as crystalline as if they had been melted, others are shattered and squeezed into slates, with a cleavage at right angles to the direction of the compressing force. The great earthquakes that happened about twenty years ago in San Francisco, Messina, and Japan caused geologists to study all the succeeding earthquakes very carefully. There is evidence that a gigantic crack in the earth's crust is extending right round the world about the line

of 40° North Latitude, and some geologists see signs that the continent of Africa has again begun to slide northward into Europe, that India is still sliding up into Asia, and that these two continents will continue to push up the earth's crust in front of them into immense wrinkles like those that now form the central ranges of mountains stretching across Europe and Asia from the Atlas Mountains through Sicily and the Balkans to the Caucasus, and on through Afghanistan and Tibet to Japan. (See map of Eurasia, Fig. 27.)

If you take a map of the world and cut the Atlantic Ocean out of it you can fit the east coast-line of North and South America into the west coast-line of Europe and Africa. Sixty years ago it was suggested that the earth's crust had cracked through along this coast-line and that America had floated westward.

During the last ten years much appreciative attention has been given to Professor Wegener's theory that the continents are great slabs of lighter material floating about on the semi-liquid core of the earth and slowly changing their positions in regard to the equator and the poles. Britain lay at the equator two hundred million years ago, and her coal seams were formed then. Great ice sheets undoubtedly buried Southern India, South America, South Africa, and Australia at the same time. Professor Wegener maintains that these scattered lands were then joined together in one great continent, so situated that the coast of Natal lay near the South Pole. The North Pole must then have been in the Pacific, where, unfortunately, its ice-cap was unable to leave any records of its existence.

CHAPTER XII

HOW THE SHEETS OF ROCKS WERE FOLDED

THERE are two great forces always fighting each other, but both continually acting on the crust of the earth. The force of contraction, owing to cooling, is always trying to drag the two sides of a continent nearer to each other, and to raise the middle of it up into the air. On the other hand, the piles of solid rock twenty miles high are, by their great weight, always trying to crush the skin of the earth down, down on to its liquid core.

Sometimes the hard skin of rocks cracks right through instead of bending, and part of the crust breaks loose from the rocks on each side of it. If the force of contraction is acting most strongly at that point, dragging the two sides of the continent together, the broken-off piece of crust may be pushed right up; but if this side-pressure is not acting the weight of the broken-off piece will force it down toward the centre of the earth. These displacements of the earth's crust are called 'faults.' Where the rocks have fallen down it is called a 'down-throw' fault, and where they have been forced up it is called an 'up-throw' fault.

The whole central valley of Scotland, for instance, has dropped down 14,000 feet, between the Highland rocks to the north of it and the southern uplands. These two great cracks can still be traced right across

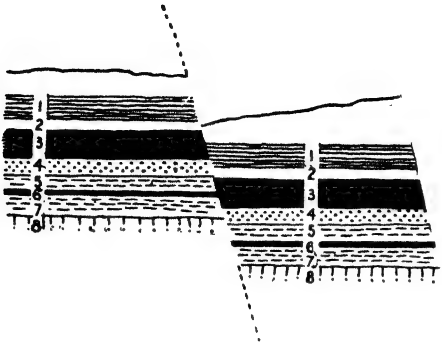


FIG. 60. A FAULT

The crust of the earth has broken through, and the rocks on the right-hand side of the fault have slipped down.

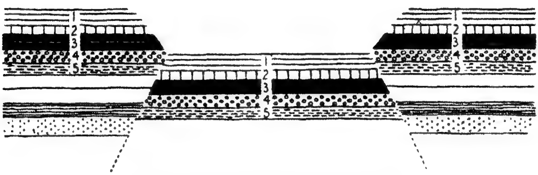


FIG. 61. THE RIFT VALLEY

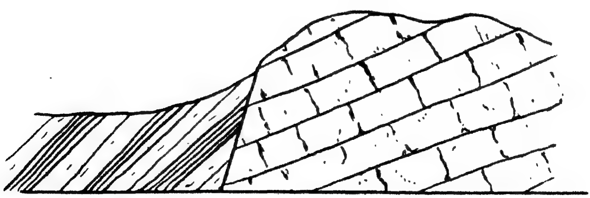


FIG. 62. FAULT, BRINGING DIFFERENT ROCKS NEXT TO ONE ANOTHER

the country from Helensburgh to Stonehaven on the north, and from Girvan to Dunbar on the south.

The coal measures once extended over the whole of Scotland, but with the exception of this slice which has fallen down into the Forth and Clyde rift valley, and so been preserved, all the rocks which contained the coal seams were washed away millions of years ago.

A geologist is always looking out for places where two different kinds of rocks are lying next to each other, because it is at these 'rock junctions,' as they are called, that the secrets of the earth's history may be explored. When the beds of rock on your right-hand side are different from those on your left you know that there has been a fault, and that one of the sets of rocks has fallen down into the earth. When the layers, or lines of stratification, of one set of rocks are lying at quite a different angle from the layers of the rocks it is resting on, then you know that the higher rocks are probably millions of years younger than the ones they are lying on; and that here is a great epoch in the world's history.

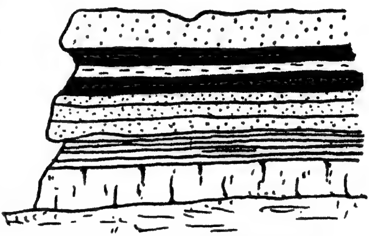


FIG. 63. STRATIFICATION AND LAMINATION

When we find one set of rocks resting on the upturned edges of another set, or 'unconformably,' as it is called, we know that after the older rocks had been laid down on the bed of the ocean a great up-folding of the earth's crust had taken place, and that these older rocks had

been bent up out of their original position and left standing on their edges, probably inside the heart of a mountain. After millions of years that mountain was worn away, and that part of the world had sunk down

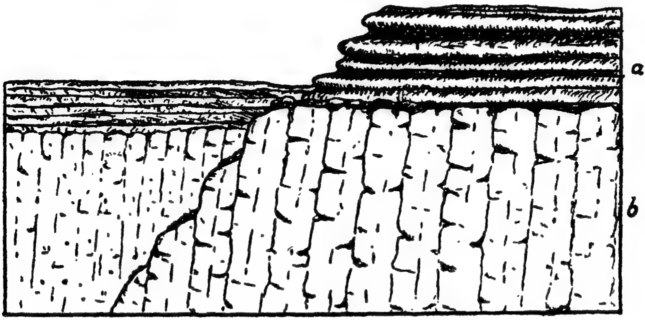


FIG. 64. BEDS OF (CAMBRIAN) SANDSTONE (*a*) ARE CONFORMABLE WITH ONE ANOTHER, BUT UNCONFORMABLE ON BEDS OF (HURONIAN) QUARTZITE (*b*)

under the sea, and then the old rocks were covered up by the layers of sand and mud that now form the newer rocks.

Whenever you come across two sets of rocks with their bedding-planes or strata lying at different angles never leave them till you have found out the reason for this, for it certainly has a history.

CHAPTER XIII

THE LAWS OF THE CRYSTALS

THE first law of the crystals is that every substance has an individual and a proper shape of its own, which it takes whenever it is allowed to do so. This is called its form of crystallization. If it cannot get into its proper shape it gets as near to it as possible.

The galena or lead crystal, used in wireless, obeys the law of fours. Its proper shape is a cube. You can easily split it into flat slices, because every slice is a cake of little cubes joined together. If you try to break it irregularly you may think you have done so, till you examine the fragments closely, and then you will find that every crumb is a collection of little cubes.

If galena is prevented from forming itself into a proper cube it still obeys its law of fours, and forms itself into two four-sided pyramids joined at their base—which is a square—and making a symmetrical eight-sided figure. Sometimes this double pyramid has all its corners cut off, so that instead of a point at each of the corners you find a small square. But in all the different shapes which it has to take it always obeys its law of fours.

Calcite is the crystallized form of limestone. It follows the law of sixes, and seven hundred separate varieties of its shape of crystals have been collected and classified by mineralogists.

There is something mysterious and enchanting in these laws of the crystals.

When the separate particles of any substance can move about freely, and are allowed sufficient time to do so, they arrange themselves in accordance with their own law of crystallization. If you break a crystal in two, and throw the parts into a solution of the same substance, you will find two complete and perfect crystals when the water has evaporated. Though you grind down crystals to the finest powder you cannot destroy this instinct for arrangement. Whenever you threw the powder into water, and caused the solution to evaporate, you would find that the identical crystals with which you started had been reproduced.

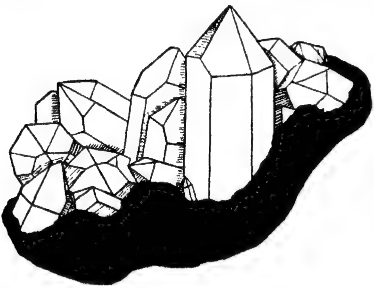


FIG. 65. ROCK CRYSTALS

The size of the crystals varies in accordance with the time taken to build them. When a solution is boiled down quickly the crystals are small; when it is allowed to evaporate or cool slowly large crystals result, but however much the size may vary the shape is always the same.

You may have watched soldiers being drilled, and seen a company 'form fours,' and arrange themselves into marching column or hollow square, according to the order of their officer. The separate particles of a substance do not need a drill sergeant to direct them to

their places. They received their orders in the beginning of time, and have never forgotten them. They may have been prevented by outside forces from obeying their commander for a hundred thousand years, yet immediately they are free to move each particle steps into its proper place, and the foreordained form of crystal appears complete and beautiful.

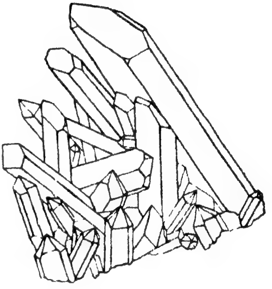


FIG. 66. QUARTZ CRYSTALS

The particles can only move about freely and form into perfect crystals when their substance is at the right heat and at the right pressure, and when there is just enough water present for them to float in. When there is too much water in the solution each particle keeps floating about on the look-out, as it were, for its partner, but the partners do not get near enough to recognize each other until the excess of water has been removed by evaporation. There is some water—called the water of crystallization—in most crystals, even in some of the hardest rocks. If this water is driven out of a crystal by heating it the particles cannot stand to their places, and the crystal falls, all of a heap, into fine dust.

When a crystal is being dissolved by an acid, or by water, each particle says good-bye to its partner, and sails off from the main body in a definite order. Very beautiful patterns are formed as each face of the crystal is being thus eaten away. The Germans, who were the

first to study them, have called these patterns 'etching figures.' The particles of every crystal have their own order for parting and reassembling; and crystals can often be identified by their 'etching figures' when other means have failed.

The law of all the crystals is that every particle has a partner, and it must go into its proper place either beside its partner, or balancing it on the other side of a line. If it is a hexagonal crystal, for instance, then everything must obey the law of that crystal, which is the law of sixes. Whatever is added at any point must be repeated six times, or in six pairs. This is the secret of its beauty. All the beautiful patterns of the kaleidoscope are formed by a similar law out of a few bits of coloured glass reflected in three mirrors. You should take a sheet of squared paper and find how easy it is to form the most beautiful designs simply by repeating the same line or dot three, or seven, or five times over, at regular intervals.

Another law of the crystal is that every particle must get as near its partner as it possibly can. When two particles come near each other each tries so hard to get close up to its partner that they squeeze out any foreign particle or other impurity that may happen to be between them. None of the particles of a crystal will have anything to do with a foreigner, so it is squeezed out and out by every set of partners as they come together, until it is finally pushed outside the sphere of the crystal altogether.

The result is a perfect crystal of a pure substance, often surrounded by a crowd of outcasts. If the

expelled foreign particle comes across a neighbour, the two unite and begin a crystal of their own substance, and float about looking for more partners. When two crystals have not room to grow they fight. But you must study the crystals and trace out the history of their loves and hates for yourself.

You have noticed the beautiful patterns made by frost on window-panes. They look like pictures of ferns and palms, and a great many other natural objects. These designs are always symmetrical, and are good examples of water crystals. After a keen frost you will see small pools in the road covered with beautiful ice crystals of all shapes and sizes. When the water cools bodily it sets into a solid mass. We cannot see any crystals in the ice because, although crystals are formed as soon as the water gets below freezing-point, the different crystals are interlocked with one another so closely, like the fingers of your two hands when you clasp them together, and the spaces between them are filled so perfectly by smaller crystals, that the whole mass becomes solid and transparent. If you look at a pool of water which is beginning to freeze, or at any crystalline substance in the stage of passing from a liquid into a solid state, you will see the crystals forming like long needles radiating from a centre, or in little bunches or clusters.

Common sand consists either of small crystals of quartz, or of the remains of larger crystals, which have been broken up. If you examine a few grains of sand under the microscope you will be surprised to see how transparent and beautiful they are.

The diamond, the black lead in your pencil, the coal we burn in the grate, and the smoke that comes from a tallow candle are all forms of one mineral—carbon.

A diamond is simply crystallized carbon. You get exactly the same result by burning a diamond in oxygen as by burning the same weight of carbon in air. Diamonds have been made artificially, and these artificial diamonds are just as real as diamonds dug up in South Africa, and are made in the same way.

Melted iron can dissolve carbon, just as water dissolves sugar. When carbon has been dissolved in iron, and a part of the mixture is suddenly cooled by being thrown into water, the carbon crystallizes out in the form of small diamonds. This proves the chemical nature of the diamond, but the stones obtained are too small to be of commercial value.

The diamonds in South Africa are found deep down in the throats of old volcanoes, the mountain parts of which have been weathered away. The natural diamonds consist of bits of carbon which have been melted by the intense heat inside the earth and afterward cooled suddenly. Diamonds have been found inside falling stars, or meteorites, as they are called. The body of the meteorite contains carbon and other minerals. It looks to us like a star because it is heated white hot by friction with our air as it rushes through it toward us. When it strikes the earth it cools, and some of the melted carbon crystallizes out in the form of diamonds.

CHAPTER XIV

THE ICE AGES

During the Ice Age the whole of this country was covered by a sheet of solid ice 3000 feet thick, which extended southward from the North Pole and enveloped the greater part of Europe, Asia, and North America.

Every living being, and all the plants even, were slowly frozen out of existence, and the Great White Death Cap grew thicker and thicker with every fall of snow, blotting out all life for thousands of years. Then it silently crept back to its lair at the North Pole, and it is awaiting its appointed time to crawl southward once more, when it will kill everything with its icy breath and bury all under its miles and miles of everlasting white death.

Geologists have not yet been able fully to discover what causes these tremendous changes of climate. We all love grandly simple explanations of natural phenomena, like the boy who wrote in his essay on "Heat": "Everything expands with heat and contracts with cold; this is why the days are long in summer and short in winter." We are, however, liable to make as big mistakes as he did, if we go too fast.

Agassiz, a Swiss geologist, visiting Scotland about a hundred years ago, was shown some groovings in the rocks at Blackford Hill, Edinburgh.

He said at once, "This is the work of a glacier."

"But there are no glaciers in this country."

"Well, I am sure those groovings must have been made by a glacier, so there must have been glaciers in this country. There used to be many glaciers in Switzerland in places where there are none to-day, and the present glaciers were not there always, because in some of the valleys, from which the glaciers are now retreating, old mine-workings have been found, which must have been cut out long before the glacier crept down and covered them."

A number of British geologists went over to Switzerland to study the work of the ice, then they examined the rock-markings in their own country, and proved beyond doubt that the ice-sheet extended as far south as London, and was in some districts over 3000 feet thick.

The rocky peaks of our highest mountains still show the great long parallel scratchings and grooves made by the glaciers which ground their way over them thousands of years ago. Huge, well-rounded boulders of granite, many tons in weight, have been left stranded on the tops of our highest glacier-rounded hills by the rolling ice sheets, which could embrace them and carry them along no farther, because they were gradually being dissolved in a warmer climate. These travelled stones or foreign boulders are made of rocks entirely different from those of the district where they are found. Many of those in Scotland have undoubtedly come from Norway, because they consist of a distinctive granite found only in Norway, and the rest have come from their parent rocks hundreds of miles away. The

FIG. 67. A BOULDER LEFT BY A GLACIER PERCHED ON A GLACIATED ROCK

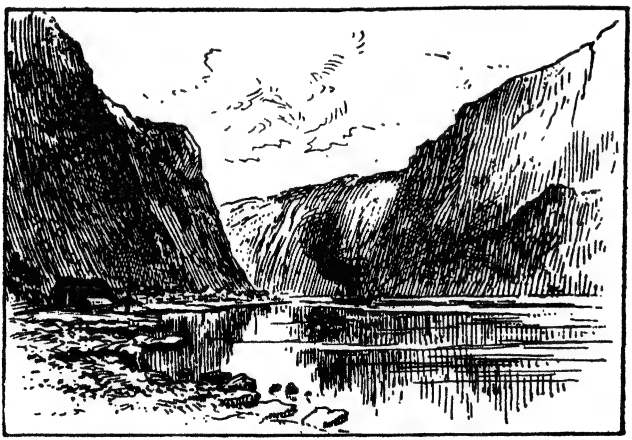


FIG. 68. A NORWEGIAN FIORD

Note how the V-shaped river valley has been widened by glaciers to the U-shaped fiord.

'boulder clay,' or 'till,' which covers so much of this country was undoubtedly left there by the ice sheet. It consists of ground-up rock, with included fragments and boulders. There is no stratification, so it could not have been laid down by water, and it is certainly not volcanic. The source of its material is very plainly indicated. Its bulk is always made up of whatever rocks happen to be at the surface of the district it is found in, or of the district a little higher up and through which the ice sheet has rolled. Wherever the boulder clay is found you may be certain the ice sheet has been, in comparatively recent times, because no other agency could have produced the boulder clay.

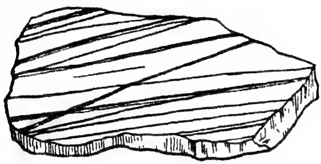


FIG. 69. ROCK SURFACE SCRATCHED BY GLACIERS IN TWO DIRECTIONS

> Though the mills of God grind slowly, yet they grind exceeding small.

Not only do the great rolling ice sheets grind slowly and exceeding small, but the boulder clay into which they grind all the different kinds of rocks is always alike, and once you have examined it you will recognize it again wherever you see it.

These ice-worn boulders were rounded and polished and covered with deep scratches. The scratches all ran in the same direction. They must have been caused either by a sharp-cornered rock being dragged across the boulder, or by the boulders being pushed along the top of a sharp-pointed rock.

FIG. 70. WHERE A GLACIER BEGINS

FIG. 71. MORAINE AT THE END OF A GLACIER

The directions of the ice scratches all over the country have been carefully noted down on maps. It is now easy to see the directions in which the great glaciers and ice sheets must have rolled across the country, by the long trails of scratched rocks and boulders they have left behind them. In every case the flow of the ice radiated outward from the high tablelands down to the sea.

The great layers of boulder clay which the ice sheets left behind them completely filled up the old river valleys, while the moving mass of ice itself ground off the tops of the mountains, thus tending to obliterate the old scenery, and reduce everything to a monotonous roundness.

When the ice had disappeared the old rivers had to begin again and carve their valleys out of the boulder clay, while many new rivers had their sources in the slowly melting glaciers.

The Glacial Period is the great yawning gulf in time, the age of death, which cuts off the ancient world of the geologists from the living world we are in to-day.

It may be difficult to believe that it can ever have been cold enough for 3000 feet of ice to cover this country, but we must accept the evidence that lies before us, and believe the facts when we find them proved. In addition to the rock-markings and the boulder clay there are in this country many other proofs of the existence of the Ice Age, such as the remains of animals and plants which live only in very cold countries, and the fact that animals and plants that

live in warm countries were abundant here before the ice came, and were all killed by it.

Many fossils of fig-trees and other tropical plants have been found in Greenland, which proves that it must have been once a warm country, and, on the other hand, there is evidence of several glacial periods in Africa, China, and Australia.

You will remember that when we were talking about the Carboniferous Period we saw there were a great many other factors that determined the climate of a country in addition to its position north or south of the equator. We have an example in the Atlantic Drift, or Gulf Stream. Hot and cold currents, whether of water or air, and the presence or absence of moisture and clouds, have a very much greater effect on climate than we generally suppose.

The coming and going of the great Ice Age was probably the result of a number of separate causes acting and reacting on one another.

The great forces of nature are so perfectly balanced that we hardly know of their existence, but a slight disturbance of this adjustment may produce great results. A trifling alteration of the helm of a great battleship will bring the leviathan gradually round in a half-circle till it sails in the opposite direction. A very slight change in the adjustment of the hot and cold currents in the air and in the sea will in time reverse the action of the weather-controlling forces, and completely change the climate of large parts of the world. Instead of the present sea-to-sky and sky-to-sea circulation of water vapour, slowly but surely carrying the land into the

ocean, the process is reversed, and the oceans are slowly piled up on top of the land, in the form of snow sheets and glaciers.

Imagine a hill-country where last winter's snow is not all melted till the end of summer. A cold summer may leave a considerable balance of unmelted snow for next winter to begin with. Year by year the balance of unmelted snow accumulates on the hill-tops. This lowers the temperature, and the water vapour floating overhead is condensed and comes to the ground as a fall of snow instead of rain. Gradually the country becomes colder and colder. The snow remains in the valleys as well as on the hills, even in the summer-time; and slowly but surely the snow sheet creeps down over the plains. Every year the water that should have run down the rivers into the sea remains on the land in the form of snow. Each succeeding snow-shower adds to the weight of the overlying layers of the mass, and presses down and condenses the bottom layers into one vast sheet of ice, which soon overspreads the whole country.

We now know that there have been not one but many Ice Ages, and that each Ice Age may be regarded as the ever-recurring winter of a year of ages. The advancing and retiring of the great ice sheets is the most important fact in the history of both animal and human life since the very beginning of this world. It accounts for the sudden disappearance of many kinds of marvellous animals and reptiles and birds, which at one time increased so wonderfully that they seemed to have taken possession of the whole world, but which were either frozen to death by the advance of the ice sheets, or

starved to death by the ceasing of the snows and the glaciers which fed their rivers and caused their rain. The countries they lived in became drier and drier, and their food withered up.

Human history begins with the end of the last Ice Age.

The great ice sheet began to disappear about a hundred thousand years ago. Asia began to dry up because the ice sheets were disappearing from the great Pamirs-Himalaya tableland.

This drying up, or desiccation, of Asia was the angel with the flaming sword which drove our first parents out of Paradise and compelled them to eat bread only by the sweat of their brow. The drying up of large parts of Asia into deserts compelled their peoples to emigrate in search of food. They followed the retreating ice sheets into countries that had now become inhabitable by human beings. The ice retreated from Europe much later than from Central Asia, where the human race originated, and wave after wave of population was pushed outward by the extending deserts and increasing famine. The earliest inhabitants of Europe followed the retreating ice sheets up from the coasts into the higher lands, only to be driven further and further north and west by succeeding waves of population, driven out of their own homes by the ever-increasing desiccation of Asia.

As glaciers are made of solid ice, it may appear strange that they are able to flow like rivers. If, however, you have ever seen the snow slipping down the roof of a house you will understand that the snow and ice slip down the sides of the mountains into the valleys in

much the same way. As more and more snow falls down and accumulates above and behind it, the mass of snow and ice in the bottom of the valley is steadily pushed downward and outward. Once it is set in

FIG. 72. A GLACIER

motion it is kept going by the constant falls of snow in the mountains above it.

Ice breaks easily, but the pieces freeze into a solid block again as soon as they are pressed together. The flow of a glacier is a succession of breakings and meltings, and freezings together again.

We do not need to try to prove by experiment that

solid ice can flow, because we know that glaciers of solid ice actually are flowing in various parts of the world at the present moment. Their rate of flow has been accurately measured now for over a hundred years, and we can tell exactly how far a given glacier will travel in a day or in a week.

Sir Ray Lankester narrates the following incident arising from their slow but regular downward flow to the region where they melt away and deposit, as a terminal moraine, the burden of rocks they have received years before in regions far above. A young man of five-and-twenty, on his honeymoon, visited the Alps, and ventured alone on to a glacier. He fell into a deep 'crevasse' or ice-fissure, and his body was not recovered. The exact spot where he fell into the ice-chasm was recognized, and the mountain folk, who knew their glacier, and its rate of movement well, told the broken-hearted widow that it would take thirty years before that region of the glacier would have moved so far downward as to reach the lowest limit, and in due course melt away. She haunted the glacier in which her young husband was entombed year after year, and at last, when she was now grey-headed and withered by time, that special tract of ice had descended so far, and was so near the thawing, thinned-out margin of the glacier, that they were able to break into it with axe and pole. Then she, an old woman, had a wonderful experience. They led her to the glacier's edge. Her young husband, preserved these thirty years in the ice, which had melted around him, and refrozen, lay there unchanged. His features were not marred by the

lapse of years, nor was his clothing rent or injured. He seemed as one asleep, resting after a long day's climb, and she, poor soul, had, during a blissful interval, the conviction that all those weary years of waiting were but a long, bad dream, that she too still was young, and was waking, as she had loved to do long years ago, in time to see him lift his lids and smile.

If it is surprising that a glacier is able to flow, it is still more wonderful that it can dig down into the ground and carry away all the soil and loose rocks, and grind the solid rocks underneath into powder. More than that, it can scoop out a lake-bottom far below the level of the sea, then climb up a wall of rock two hundred feet high. Water cannot flow uphill! How can ice do it? How can a glacier dig stones out of the ground and carry them on to the top of a hill?

When you've been skating, have you never seen a stone sticking nearly half-way into the ice, and tried to get it out and couldn't?

Without there being any thaw at all, the weight of the stone pressing on the ice gradually melts a thin film of the ice it rests on, then, sinking through that film, the stone melts another film, and so on, until it slowly presses its way through the ice.

Now, if its own weight of a few pounds can press the stone down into the ice, what would happen if a cake of ice were lying on top of the stone when the stone was resting on a rock?

The weight of the block of ice pressing itself down on top of the stone would cause the stone to bore its way up into the ice.

But if the first stone were resting on top of a second stone, that would be pressed up into the glacier too, with any gravel and small stones which might be there.

Everything that the glacier rested on would be pressed up into its body. Thus the bottom of the glacier would be like a patchwork quilt made of rocks.

The bodies of all the loose rocks would be pressed up into the body of the glacier and held in position there. The fragments of rocks themselves would have a certain power of moving about inside the ice. If their front edges caught against anything the rocks in the glacier would either dig down into the obstruction or would be turned over by it.

Imagine a string of gigantic rock beads of all sizes from six inches to twenty feet in diameter. Imagine them strung higgledy-piggledy, one after the other, without any regard to size.

Imagine them not round and smooth, but as angular and jaggy and scratchy as possible. Take a thousand of these strings of scratchy rocks. Lay them side by side across the country. Tie all their front ends to a gigantic harrow-beam a mile long. Harness an irresistible force to this harrow-beam that must drag all the strings of jagged rocks down dale and up hill, down, down into the sea. Pile a mountain of ice all along your band of strings of rocks, so that its tremendous weight will press the point of every rock right down through everything till it reaches the solid crust of the earth. Imagine this awful scratching machine dragged across the country for thousands and thousands of years, and you will have some idea of what a glacier can do.

CHAPTER XV

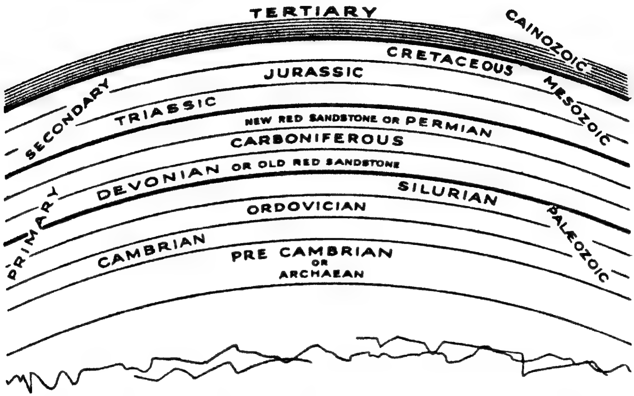
CLASSIFICATION OF ROCKS

THE total thickness of the whole series of sedimentary rocks as now measured by geologists is thirty miles. They have been built up of tiny grains brought down by the rivers and piled one above another, and the time it has taken to build them is at least one hundred millions of years.

All the rocks of the world have now been classified into five great divisions; they are numbered 0, 1, 2, 3, 4, and named Archæan or Pre-Cambrian, Primary, Secondary, Tertiary, and Quaternary. Early geologists divided all the rocks into three kinds. The first they called Primary or Palæozoic, from two Greek words—*palaios*, meaning 'ancient,' and *zoe*, 'life'; the second they called Secondary or Mesozoic, or 'middle life'; and the third they named Tertiary or Cainozoic, meaning 'recent life.'

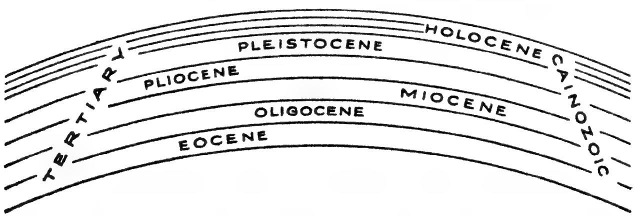
It was not long, however, before they discovered that there were rocks far older than those they already had named Primary, so they called these still older rocks the Archæan, from a Greek word meaning 'beginning.' These Archæan series are the oldest rocks, and contain no recognizable trace of life, and may be considered as the foundation rocks on which all the others have been laid down. When men of science began to calculate the ages of the various rocks they found that

CLASSIFICATION OF ROCKS



The Tertiary Rocks are subdivided into six groups, according to their ages

SUB DIVISIONS OF TERTIARY ROCKS



The Quaternary Rocks are subdivided into three groups

SUB DIVISIONS OF HOLOCENE OR QUATERNARY ROCKS

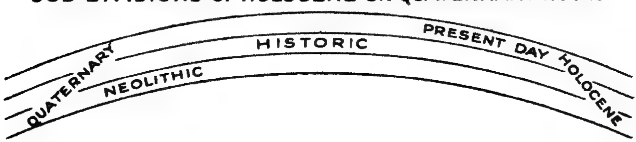


FIG. 73

the Tertiary rocks were at least three millions of years old. After these come a whole series of later rocks, far more important to us than all the rest put together, because they contained the remains of man. It was, therefore, decided to restrict the old name Tertiary to the rocks which were laid down before the first forerunners of man appeared on the earth, and to call all the rocks which have been formed since then Post-Tertiary or Quaternary.

There were first three divisions—Primary, Secondary, and Tertiary. Then the Archæan class was put in before the Primary, and the Quaternary, or fourth class, was added after the Tertiary.

The names used in geology are very confusing, and that is why so many people who commence to study the science give it up in despair.

The science has grown rapidly, because a great many people have been working at it separately all over the world. Each man thought that the names he chose for the different rocks were the best. Some writers gave the same name to two or three different kinds of rocks, and five different writers would give five different geographical names to the same kind of rock. At first there was no uniform principle of naming the rocks. Many of the rocks belonging to the Old Red Sandstone formation, for instance, are not red, and are not sandstone, and would not now be named 'Old.' Indeed, this period in Scotland was characterized not by its sandstone, but by its great lakes and tremendous volcanic activity.

Cambrian rocks are found not only in Wales, where

these rocks were first studied and named, but in China and in the Argentine and, in fact, all over the world.

All geologists have now agreed to classify the rocks according to the geological period in which they were formed.

Geological time is fossil time.

All the rocks are now arranged in the order of creation of the fossils they contain, that is, in accordance with the particular fossils that first appeared on the earth during the age in which these particular rocks were being formed.

It is necessary to understand thoroughly the principle of these geological names.

The name is not applied to any particular rock, or kind of rock, or method in which rocks came into existence, but to a whole series of rocks formed during the lifetime of a group of fossils.

The particular name was given originally to a particular group of rocks, either because of the most characteristic kind of rock in the group, or because of the particular country or locality in which that group of rocks was first discovered or described.

Now this name has been taken away from the group of rocks it was at first given to, and applied to the period of geological—that is, fossil—time during which that group of rocks was laid down.

We speak of a Norman church, an Elizabethan drama, Queen Anne furniture, or Early Victorian costumes, not because the church is in Normandy, or was actually built by Normans, but because it was built in

the style of architecture that was introduced during the time the Normans dominated England.

Similarly, we do not mean that Queen Elizabeth wrote the drama, or that Queen Anne made or used the furniture, or that Queen Victoria wore that kind of costume in the early years of her reign, but we mean that that kind of drama, or furniture, or costume was characteristic of the period.

In the same way an Old Red Sandstone volcano doesn't mean a volcano made of old red sandstone or one which erupted old red sandstone materials, but a volcano that was in eruption during Old Red Sandstone time. Cambrian rocks mean rocks belonging to the geological period during which the old rocks in Wales were formed. This is clear from the fact that the same dominant fossils are found in all these rocks.

Before the Union of the Crowns England and Scotland were ruled by separate kings reigning at the same time, and the countries were called by different names, yet the people of the two countries were really descendants of the same great races, and had reached about the same stage of civilization. In the same way the Devonian rocks of England were being formed at the same time as the Old Red Sandstone rocks of Scotland.

Supposing a skeleton were dug up from the field of the battle of Bannockburn, you could not tell by examining the bones alone whether it was a fossil Englishman or a fossil Scotsman. If, however, part of his armour, or clothing, or equipment happened to be preserved you might be able to tell from these to which nation he belonged.

The Devonian rocks of England contain the remains of salt-water animals, and must therefore have been laid down in the sea, while the Old Red Sandstones contain the fossils of fresh-water animals.

We conclude, therefore, that during the period in which both these sets of animals were living on separate parts of the earth, at the same time, a ridge of hills had risen above the bed of the sea. This ridge created an inland lake by cutting Scotland and the land now lying under the North Sea off from the main ocean, in which the Devonian rocks were being laid down.[1] The great rivers of Europe flowing into this shallow inland sea, or great lake, kept its water fresh, while the water on the other side of the ridge was salt, and sea-animals lived on the outside and fresh-water animals lived on the inside of the ridge.

The geological succession of rocks has to be remembered in the same way as the succession of the Kings of England. Geological periods are the reigns of groups of fossils which appeared on the earth in bygone ages, fought for supremacy, ruled, and were in their turn either exterminated by great changes of climate, or subdued by the higher forms of life which followed them.

This general arrangement of rocks extends throughout every country in the world, and they are always found in the same order. You must not, however, imagine that the earth has all these five skins of rock lying over every part of its surface, and that if we were to dig down anywhere we should come to first

[1] See map of North Sea Plain, Fig. 19.

Quaternary, then Tertiary, then Secondary, then Primary, and lastly Archæan rocks, and that finally, if we passed through these, we should reach a liquid core.

On the contrary, the newer rocks have been mostly built up out of the remains of older ones. Great areas of the older rocks had to be destroyed in order to furnish material to make the new rocks out of.

The skin of the earth is always wobbling and shrinking and crinkling. Whenever a portion of the earth's crust emerged from the water it was gradually eaten away by the rain, and carried back into the sea to be used over again in making new rocks.

During the time these exposed parts of the earth were being crumbled into grains, and carried out to sea, the inside of the earth was growing colder, and therefore smaller. The outside skin had to shrink and wrinkle to fit itself again to the inside core, and thus a new set of continents was made, for a new family of rivers to devour.

When we find Quaternary or Post-Tertiary rocks in any part of the country, it is probable that Tertiary, Secondary, Primary, and Archæan rocks are lying underneath, but wherever the Archæan rocks appear on the surface we may assume that all the newer rocks which once covered them have been washed away, and that we may be standing on the old skin of the molten earth.

The rock crust which covers the earth is hard and brittle. When it has to adjust itself to internal changes it not only heaves and wrinkles, but it often cracks. Then the molten rock inside, subjected to terrific heat

and pressure by its imprisoned gases and the tremendous weight of miles of rock pressing down upon it, finds out the crack, bursts up through it, and flows over the surface of the earth. In some parts of the world these outflows of lava are hundreds of feet thick and cover thousands of miles of country. They overlie, and are sandwiched in between, all the different varieties of sedimentary rocks.

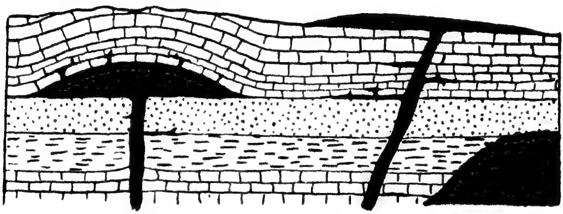


FIG. 74. DIAGRAM TO REPRESENT THE RELATION OF IGNEOUS ROCKS TO STRATIFIED ROCK

The igneous rocks (black) have been forced up from beneath. (After Gilbert.)

The white-hot liquid inside the earth is always endeavouring to spout up through its crust. When it reaches the surface it flows out in the form of lava and cools rapidly. Sometimes, however, the crack does not open right up to the surface, or else the melted lava when it gets up into the cold rocks near the top of the crack cools, sets solid, and chokes up the crack. The stream of white-hot rock, welling up from beneath, finding the trap-door shut down upon it, spreads to right and left under the floor, forces great areas of stratified rocks out of their beds, and flows underneath

them and floats them up, just as rising water in a well or cellar will float up planks of wood which were originally lying upon the bottom of it.

When the melted rock succeeds in reaching the surface and pouring itself out it cools very rapidly, and is called lava. When it forces its way in beneath some other set of rocks it is called an intrusive sill.

If the crack is a large one, or if the mass of white-hot rock keeps pouring up till it has melted out for itself a big round hole in the rocks it has come through, it becomes a 'vent' or permanent chimney for the 'fires' of the underworld, and if it continues spouting up rubbish enough to make a conical hill all round it it is called a volcano.

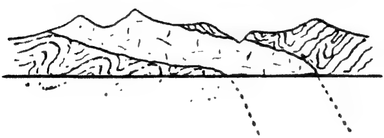


FIG. 75. SILL OF BASALT (OR GRANITE)

When the volcanic rock cools and sets solid inside the throat of the volcano out of which it has been pouring it is called a volcanic plug. Owing to its hardness this plug of rock which has cooled in the throat of the volcano is often left standing after all the rest of the volcano has been eaten away by the rain, or ground away by the glaciers. Whenever you see a hill rising almost perpendicularly from the country all round it, you may be pretty sure that it is the plug of an old volcano.

These isolated hills with their steep, rocky sides formed splendid natural fortresses, on which a small body of fighters could easily defend themselves against

a horde of enemies. Many of our most famous castles are built on the top of these volcanic plugs, and important towns have grown up round them.

For instance, Edinburgh Castle Rock is a solid plug of igneous rock which now fills the hole in the earth through which melted lava at one time poured up and flowed over the surrounding country. Now it is left like the stalk of a mushroom from which the head has been removed.

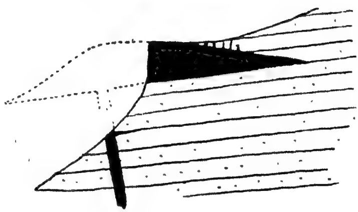


FIG. 76. DIAGRAM OF A SILL, SHOWING ITS FORMER EXTENSION AS A LACCOLITH, OR DOME-SHAPED INTRUSION

Originally the whole mass of rock was shaped like a gigantic mushroom. The stem was the hole in the ground through which the melted rock had surged up, and the head of the mushroom was the lava which had flowed out over the surface of the earth before cooling. You may see something like this on a very small scale in a paved street where the square paving-stones have been fixed with pitch. In hot weather the pitch is heated by the sun and oozes up from between the paving-stones, and forms on the surface into little black balls or cakes.

Long ages ago, when the cold crust of the earth was much thinner than it is now, the mass of boiling rock inside, crushed down by the tremendous weight of solid earth lying on top of it, found a crack in the shell through which it could spout up. You have often seen an egg with a little crack in its side put into a pan to

boil. You did not know the crack was there, but when the egg became heated the liquid inside the shell wanted to expand, as everything must expand when it is heated, so it pressed all round and round the inside of the shell, until it found the place weakened by the crack. It forced itself through the crack, and solidified when it came into contact with the boiling water outside.

This was what happened on a much larger scale when the Edinburgh Castle Rock came out of the inside of the earth, which at that part of Scotland was then thousands of feet higher than it now is. The earth was a ball of hot liquid with a shell of rock surrounded by a mass of air, just as the boiling egg in the pan is surrounded by a mass of water. The melted rock was squeezed through the crack in the softer rocks above it, and as the lava passed through the hole, being intensely hot itself, it melted the rocks it was pouring through, and made the hole bigger and bigger, like a hot poker being pushed through a sheet of ice. When the melted rock reached the outside of the earth's shell it became solid and spread out like the white of egg that has boiled through the crack.

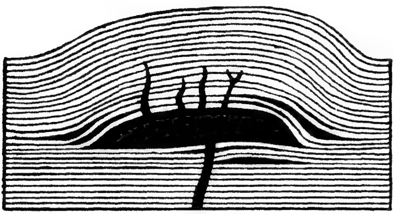


FIG. 77. IDEAL CROSS-SECTION OF A LACCOLITH

All the mass of rock that formed the head of the mushroom of cold lava, so to speak, has been ground down by the rivers and glaciers which carved out the

valley now filled by the Firth of Forth. The river, flowing over the softer rocks through which the boiling basalt rock had poured up, gradually washed them away. The plug of cold basalt was very much harder than the surrounding rocks, which in the succeeding ages the river has worn away grain by grain and carried out into the sea.

Here is a geologist's lunch of three sandwiches and a biscuit which may help you to remember the order of the ten sets of sedimentary rocks. It consists of a thick ham sandwich, a brown bread and watercress sandwich, an egg sandwich, and a water biscuit with a splash of chocolate on it.

The plate represents the Archæan, or Pre-Cambrian rocks, the hard old crust of the earth; the thick ham sandwich the Cambrian, Ordovician, and Silurian rocks (with the first traces of animal life), very much altered by heat and chemical and mechanical changes; the brown bread and watercress sandwich represents the Carboniferous Period, with its enormous development of vegetable life lying between the Old Red Sandstone or Devonian rocks and the New Red Sandstone or Permian; the egg sandwich will stand for the three Secondary series of rocks, Triassic, Jurassic, and Cretaceous, with their abundant remains of reptile and bird life; and the thin water biscuit, with its many complicated, wafer-like layers, represents the rocks of the Tertiary Period, during which higher animal life developed, and the very thin splash of chocolate on the top the Post-Tertiary or Quaternary rocks, containing the history of the ascent of man.

CHAPTER XVI

THE MEANING OF FOSSILS—THE EVOLUTION THEORY

For I dipt into the future, far as human eye could see,
Saw the Vision of the world, and all the wonder that would be.

. . . .

Yet I doubt not thro' the ages one increasing purpose runs.
TENNYSON, *Locksley Hall*

THE science of geology has been built up by the interpretation of fossils, and the theory of evolution has been established by comparing the fossil remains of extinct animals with the animals that are living to-day.

The beginning of all knowledge is the collecting of facts. After the facts have been collected they require to be classified and arranged.

Many different ways of arranging plants and animals have been attempted. For centuries independent workers tried to arrange them in the order they themselves thought best. Confusion was the result, and very little progress was made. Over a hundred years ago many scientists began to realize that some plants and animals were much more highly organized than others; and they agreed that the best way of arranging and classifying the different plants and animals would be to begin with the simplest forms of life and gradually lead upward to the more complex organizations and higher intelligences.

The students of natural history arranged all their

animals (both with and without backbones) and birds and fishes in this order, and the geologists classified their fossils, and the botanists placed all the plants and trees in similar order; each arrangement commencing with the simplest form of life and leading upward to the higher.

The next great discovery was made when the geologists began to compare their fossil animals and plants with the living animals and plants, not for the purpose of proving that they were in all important points the same, but for the purpose of finding out how much, and in what respects, the fossil forms differed from the living animals of the same kind.

This comparison showed that the fossils found in the newer rocks differed very little, if at all, from the living forms of the same animal, and that the older the rocks were in which a fossil was found, the more pronounced was the difference between it and the living animal of the same sort.

It was next seen that the fossils found in the lowest, and therefore the oldest, rocks were only those of the very simplest kinds of animals; while the more recent rocks contained the remains of the more highly organized animals as well as of the simpler ones. If these higher animals had been living at the time the lowest rocks were formed these rocks would certainly have contained their fossils as well as those of the lower animals. The lower rocks must, therefore, have been formed at a time before the higher animals came into existence; and the very lowest rocks, which contain no fossils at all, must have been laid down grain by grain in the far

back time when the earth was without form and void, before any living thing had been created.

Darwin came and saw all the plants and animals and fossils arranged in order, and the thought struck him: "This is not merely an arrangement of specimens in a museum in an order which enables anyone to know where to look for a particular plant or animal, but this is the order in which all plants and animals were actually created. This is not a museum collection, but a picture-history of the whole inhabitants of the world from the very beginning of time up to the present hour, and these fossils are monuments of the struggle of life to find proper expression for itself ever since the world began."

This idea was the foundation of the theory of evolution.

Evolution means an unrolling or unfolding.

Something cannot come out of nothing. Scientists are now agreed that even the lowest form of life cannot be produced by dead matter. No higher form of life could be evolved from a lower form, unless God had originally given the lower form power to rise into the higher when its surroundings allowed it.

Evolutionists believe that the world is still being created, that men and things are better now than they were a thousand years ago, and that they will continue to grow better and better.

Geologists are slowly spelling out from the fossil records in the rocks this great story of the upward struggle of the living world toward a higher and higher life. The animal part of man's nature he shares with

all the other animals in the world. He forms part of one vast living community, "that great column of being whose base is in the sea, and on whose summit stands man."

This means that all the different animals in the world are descended from the one original animal. The same life is in the flea and the elephant. They are related to each other and both have had a common ancestor.

This is true in spite of the fact that in appearance these creatures are so entirely different.

Although it seems incredible at first, we shall be helped to understand it if we think for a minute of the great changes that man has brought about in the domestic animals in the comparatively short period during which he has controlled them.

What a contrast there is between the little Shetland pony and the giant Clydesdale, and how unlike they both are to the racehorse! Yet they are all descended from the one wild horse, and their distinctive qualities are largely the result of man's interference. If he wants to produce a bigger horse than any living he selects the two biggest horses he can find, and breeds from them, and gives both them and their offspring as much food as they can eat. He goes the opposite way about if he wants a smaller horse than any living. Racehorses are bred for speed, Clydesdales for strength, hunters for speed and strength, and carriage-horses for beauty.

All the different varieties of dogs, from the toy spaniel of six inches to the great St Bernard, have been bred by men from the original wild dog or wolf. Pigeons and every other animal man has domesticated

have had their characteristics changed in many different directions. If you remember how all these varieties have been artificially produced by men in a few thousand years you can easily understand that in the course of millions of years it is quite possible for all the existing varieties of animal life to have been produced by natural selection.

We shall understand this term if we remember Darwin's declaration that all the different kinds of plants and animals have been produced by nature from one common ancestor, in the same way that man has produced new breeds among his domestic animals. All variations from the original type are in the first place the result of accident. If the owner of the animal approves of this accidental variation he selects it for specially favourable treatment, gives it plenty of food, and tries to secure that it shall attain to full development, and produce offspring having the same special qualities as itself. If he disapproves of the variation he kills it, or prevents it from having offspring. This is human selection. Nature favours certain accidental variations in the same way, but the variation has to fight for its own hand and secure its own survival. Nature selects her favourites by starvation. There is not nearly enough food in the world for all the animals that are in it. Great numbers of them, therefore, must die, and for the whole of them life is a continual struggle for food, in which the strongest conquer and the weakest are killed, or left to die of starvation, because all the food has been eaten up by the strong ones. If by an accidental variation any animal is bigger, stronger, quicker,

or wiser than its fellows, it has a much better chance in the fight for food. It survives and produces offspring, and may in time establish a new breed superior to the old one.

The conditions of life in the animal world are always changing. There may be an alteration in the climate of the country where the animals live, or in the quantity, distribution, or nature of their food, or a new race of more powerful enemies may arise to prey on them. Those die who are stupid enough to go on trying to live as their fathers did; while those who can change their way of living to suit their altered circumstances survive, and produce offspring still better fitted to live under the altered conditions of life. This is known as the principle of adaptation to environment.

You will understand the meaning of these principles of natural selection, adaptation to environment, and the survival of the fittest if we trace their working in the case of an animal whose family history for three million years is now definitely known.

Let us try to discover the secret of the splint bone in a horse's leg. The horse has no use for this bone, and the men who had studied it were for long puzzled to know why this bone should be there at all. The geologists discovered that this splint bone contains the secret of the horse's ancestry and tells the story of its development from a very small animal.

What we call the leg of a horse is really its hand or foot, not its arm or leg. Its hoof corresponds to your finger- or toe-nail; and that is why the horse is not hurt when the blacksmith drives nails into its hoof as he

shoes it. What we call the knee of the horse in reality corresponds to our wrist, and the next joint to our elbow. In the hind-limb the hock is really the heel, and the next joint above is the knee. The upper portions of the horse's arms or legs have been concealed within its body. You can feel its real shoulder-bones up near the base of its neck. The horse walks on the tips of its middle fingers and middle toes, which have been greatly enlarged by constant exercise. You will see at once that this is true if you watch a horse getting up or lying down; and it is because of this peculiarity that when a cart-horse falls in the street it cannot get up itself, but the cart has to be unharnessed and taken away before the horse is able to rise.

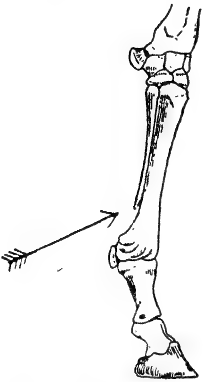


FIG. 78. THE SPLINT BONE IS EMBEDDED IN THE FLESH OF THE HORSE'S LEG, AND THEREFORE CANNOT BE SEEN. IT CAN EASILY BE FELT, BUT CHOOSE A QUIET HORSE

The earliest ancestor of the horse was the Eohippus, whose fossil remains have been traced into the oldest rocks of the Tertiary Period. It was a little animal, very like a fox-terrier, but less than a foot in height, even when full-grown.

The active principle of evolution is that any organ of the body which is used becomes larger and stronger; and, on the other hand, any part of the body which is not used grows weaker and smaller, and eventually disappears altogether.

Some fishes which live in dark caves have apparently no eyes, but when the skin covering the head is removed rudimentary eyes are found under it. They are useless for seeing with, but they prove that the fish is descended from ancestors that had eyes and used them.

The earliest distinct forerunner of the horse was very like a small dog. Its teeth were small, and it lived in a

FIG. 79. REMOTE ANCESTOR OF HORSE THAT HAD FIVE FINGERS AND FIVE TOES

swampy country and fed on soft, juicy plants. It had five fingers and five toes just as you have, but it began to walk principally on the middle finger or middle toe of each foot, and as a consequence its middle finger became longer and stronger than the others, which grew continually weaker and smaller, till in the course of two million years they have practically disappeared.

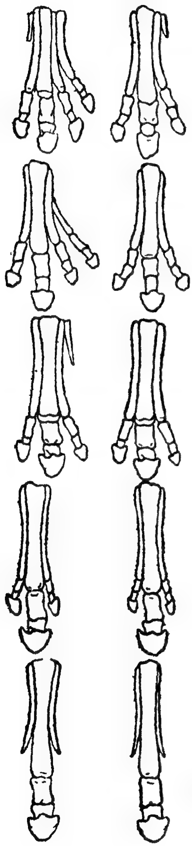
The great-great-grandfather of the horse lived in the Eocene Period, and is therefore called the Eohippus. It had four large toes on its forefeet and a fifth

imperfect one, but on its hind-feet it had only three large toes, each with a hoof, and the middle toe-hoof was larger and longer than the others. The next stage of development was reached in an animal which has been called the Protorohippus, or 'rising horse'; it had only four toes on its forefeet, and three on its hind-feet. In the fossil rocks of the Oligocene Period the horse is represented by the Mesohippus. It has still three toes on its hind-feet, but one of the fingers of the forefeet has disappeared, and on each leg there is now one large central toe and two small ones.

In the next stage, the Miohippus, the side-toes have still hoofs, but they are gradually becoming smaller, and dying away from disuse. Finally, among the rocks which contain the fossils of man's own ancestors are found the remains of the Hipparion, which was the immediate ancestor of our horse. Now the horse's unused hoofs have entirely disappeared, leaving only the two little splint bones to mark the place where these side-hoofs belonged.

Even at the present day a foal is sometimes born with three hoofs at the end of each leg. These 'throw-backs,' as they are called, prove that the horse is descended from an ancestor that had many hoofs. While these changes were going on in the foot of the horse, in order to adapt it to the changed conditions of life, the rest of its body was altering in a similar way. As its middle finger gradually grew longer and broader, until it has now become its foreleg, the horse's neck and head had to grow longer to enable it to reach down to the ground and eat the grass, and at the same time its front

EVOLUTION OF THE HORSE'S FOOT



Rocks in which Fossils are found.	Name of Extinct Ancestor of Horse.	Fore Feet.	Hind Feet
Lower Eocene.	Eo-hippus, or "beginning horse."	4 toes and splint of 1st digit. All toes touching the ground.	3 toes and splint of 5th digit.
Upper Eocene.	Protoro-hippus = "Rising horse."	4 toes but no splint. All touching the ground.	3 toes but no splint.
Oligocene.	Meso-hippus = "Midway horse."	3 toes and splint of 5th digit. Side toes still touching the ground.	3 toes but no splint.
Miocene.	Mio-hippus and later Hipparion.	3 toes, But side toes not touching ground, and withering away, because never exercised.	3 toes,
Pliocene and Pleistocene.	Equus.	1 toe, And splints of 2nd and 4th digits.	1 toe,

NOTE.—These bones are not drawn to scale. The last pair are much larger than the first. As the animal which became the horse increased in size from that of a small fox-terrier 11 inches high, to our present Clydesdale, its feet would increase proportionately.

FIG. 80

teeth were narrowed and sharpened so as to become better fitted for cutting the hard grass of the dry plains which it now fed on, and its back teeth became broader and more grooved, and so better adapted for grinding up this grass.

In a similar way the bodies of all living animals have been gradually but continually altering so as to enable them to live amid altered conditions of life, in accordance with the principle of adaptation to environment.

You could easily tell the difference between a horse and a bull or a donkey, and if you had studied the anatomy of those animals and knew all their bones you could soon say to what kind of animal a particular bone belonged. If you knew all about the bones of a horse, and came across a fossil bone, you would be able to tell which of the horse's ancestors this bone belonged to.

The development of life from a low to a higher form can be traced in much the same way. A geologist who has studied fossils can tell at once what kind of animal a particular bone belonged to, whether such an animal is still living to-day or not, and in what rocks similar animal remains will probably be found.

No such gradual development from a lower animal to a higher can be traced in the case of man. His remains do not appear till near the close of the fossil record. He arrived very late in the day, but he arrived fully developed, and with a brain several times larger in proportion to his size than that of any other animal of the ape family. Man and monkey, like the flea and the elephant, are both descended from a common ancestor, but man has certainly not descended from a monkey.

In body man is insignificant, in mind supreme. Have you ever seen a sheep hung up by the hind-legs at a butcher's door, and noticed that it is taller than you are, weighs heavier, and is in many respects a superior animal?

The skeleton of the earliest known man differs very

FIG. 81. FOSSILIZED HIND-LIMB OF HIPPARION IN BLOCK OF LOWER PLIOCENE MARL

little from the skeletons of some primitive races living now. The brain of the man of the Stone Age was as big as the average brain to-day. The only advantage we have over him lies in our machinery for education, which enables us to use the knowledge gained by our fathers, instead of having to find out everything anew for ourselves.

Like every other animal in nature's realm, man is subject to the laws of natural selection, adaptation to

environment, and the survival of the fittest. But he works out his salvation with his mind rather than with his body. When changed conditions of life compel him to alter his way of living he alters his clothes or his tools instead of his skin or his bones. In a cold climate man does not adapt himself to his environment by growing a covering of thick hair like a bear, but he kills the bear and wears its skin. Instead of growing horns out of his own skull, he invents a spear, tipped at first with the horn of another animal, then with flint, and lastly with steel. The wooden club serves him as well as a lengthened arm; the stone knife is better than any claw he could develop from his finger-nails, and the arrow or the flying stone gives him the victory over animals whom he could never overcome by swiftness of foot. The thick walls of his rude hut are a better protection from his enemies than the hide of the rhinoceros or the shell of the turtle, and he stores up food for the winter instead of accumulating a store of fat in his own body, as most other animals do.

It is this power of adapting itself to all the varying conditions of life that has made the human race immortal on the earth. Every other animal is confined to a certain part of the earth's surface, and can exist only under given conditions. Man alone has spread and established himself over every part of the world at once. Owing to changes of climate and other causes great areas of the earth's surface have from time to time become incapable of supporting life, and many races of animals which were once dominant have been wiped out of existence altogether. The whole of the world has

never yet been rendered uninhabitable at the same time, and therefore, though millions of the human race have perished, there has always been a remnant left somewhere, which under happier circumstances has spread and repeopled the earth once more.

It is because man makes changes in his clothes or his tools instead of in his body, in order to adapt himself to altered conditions of life, that there is so little difference between the skeleton of the earliest man and the human skeleton of to-day.

Our knowledge of the evolution of man from a lower state of civilization to a higher has been gained not by studying his bones, but his tools. At this point the geologist hands over the task of writing the history of the world to the archæologist and the anthropologist. The fine workmanship of hundreds of flint implements now collected proves that man had attained to a comparatively high state of civilization in the Stone Age, and his body was in many respects superior to ours.

CHAPTER XVII

THE TASK OF THE GEOLOGIST

> When I see evidence for facts, they are God's facts, and they will be only my help in the end, if I can duly make use of them. The peculiarity of the Bible was that it lived through all revelations of unexpected facts.
>
> PRINCIPAL RAINY, *Life*, vol. ii, p. 275

IF geology is so simple, it may be asked why it is that we need all these hundreds of books about it.

If we consider, however, that it would take a hundred books to describe every country in the world, with all its mountains and rivers and valleys and towns, and to give the history of all its kings and peoples and buildings and roads from the beginning of time up till now, the task of geology is not so simple after all.

It attempts to give an account not of one world, but of twenty different worlds, for every set of rocks represents a separate world, and contains a history of its inhabitants and all their battles, struggles, and changes for perhaps millions of years.

If all these worlds which the geologists have to describe were separate from each other, and still in existence, the work of describing them would be comparatively simple. It would only be necessary to visit each world in turn and write a careful account of whatever was found on it; but the past worlds we deal with are buried one inside the other.

At first sight, it seems difficult to understand how

geologists know of the existence of these different worlds lying one underneath another, if they have never cut down into the earth to find them.

We shall be helped if we look at a nest of Chinese baskets.

When I take off the lid of the violet outside basket we find an indigo-coloured basket inside it. When we open the indigo basket we find a blue one inside; inside the blue a green; inside the green a yellow, then an orange, then a red.

You see, now, as I place them all out on the table that it would be quite easy to describe each basket in turn. This red one might be the world in the Cambrian Age. The orange, in the Ordovician Age. The yellow, in the Silurian Age, and so on. From the fossil remains in the rocks of each of these ages we could repeople each world with its living things, and judge of its climate and other conditions of life.

But it is still not easy to see how the geologists can separate each of the different layers of rock and reconstruct the world as it existed at the time these rocks were laid down. They certainly cannot skin the earth like an onion, and lay all the different layers of rock out on the table like these Chinese baskets.

This we can best explain by putting the seven baskets one inside the other.

Now, when I push my finger into the side, so as to make it bulge out and represent a mountain on the earth's surface, I press the seven different layers of straw into a little dome round my finger. If I were to shave off this dome level with the rest of the side of the basket,

as the mountains are removed by denudation, I should have planed away the raised part of each of the seven baskets, and should find seven concentric circles of the different colours, each being an edge of one of the baskets I had cut through. If I press the ends of the basket together so as to make the side bulge out, and then cut away the raised pieces level with the rest of the side, I should have the cut edges of the six underneath baskets appearing, first indigo, then blue, green, yellow, orange, and red; then, on the other side of the cut, the orange edge would come again, then next to it the yellow, green, blue, and indigo.

Imagine that some unknown but very active force imprisoned within the nest of baskets, and constantly trying to get out, had caused the surface outside to be covered with domes and puckers and folds, and that all these raised parts had been shaved off, and showed everywhere some of these seven colours, one below the other. Well, then, if I came across these different coloured edges of straw always in the same order on the outer basket, I should naturally conclude that the nest was built up of these seven different baskets, placed one inside the other.

The earth's crust has been crumpled by constant contracting and wrinkling; the resulting raised portions have been shaved off by denudation, and thus the underlying rocks have been exposed for our inspection. But for this upheaval of great folds of the earth's crust into mountains and tablelands, and their being cut into and carried away by the rivers, we should never have known anything of the rocks underneath us.

The result of the earth's contraction has varied so tremendously that the brittle skin of rocks has been forced up in waves of every height from a few feet to twenty miles. Denudation has been so continuous and universal that the top of every one of these waves has been cut through, and every layer of rock in the earth's crust now lies uncovered on the surface somewhere. The earth's surface is made up of a patchwork of the shoulders of masses of rock that have been forced up from all the different depths and had their heads cut off. By adding together the thicknesses of the edges of all the separate layers of rock that have been thus cut through, geologists have found that the total thickness of the sedimentary rocks in North-west Europe is over 75,000 feet.

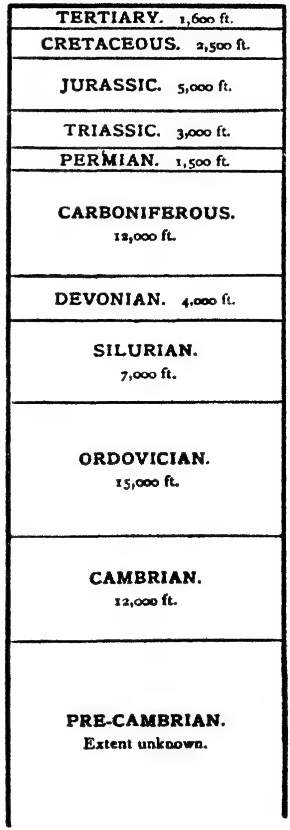


FIG. 82

Here is a diagram showing the principal divisions of these rocks, which you should copy and learn by heart.

If I were to hand you a piece cut out of the side of this nest of baskets you could easily distinguish the different layers by their colours, and tell me which of the baskets each belonged to, but the different sets of rocks which make up the earth's crust are not separately coloured for the geologist.

You can at once see the difference between a bed of limestone and the sandstone lying above it and the shales beneath, but you could not say to what period of the earth's history these rocks belonged, and even though you came across a seam of coal you might be quite wrong in saying that the rocks it was found among belonged to the Carboniferous Period, because seams of coal are found in rocks of many different periods.

The different rocks can be distinguished by the fossils which they contain. Geologists laid the foundation for the evolution theory by showing that the lowest, and therefore oldest, rocks contained only the lowest forms of life, while each succeeding newer and higher set of rocks contained the fossils of higher and higher forms of life. After the truth of the evolution theory had been fully demonstrated by the other sciences geologists were able to use it to check their classification of the rocks, and so to be sure that if a rock contained a particular set of fossils it must have been formed during a particular period.

If a coin bearing the name of a certain King of England or Emperor of Rome is found in a grave, or in the foundation of a building, that coin determines the date of that grave or building, because we know that the coin could not have been put there before that king came

to the throne, and was probably put there during his reign, or soon afterward. There are many extinct animals whose fossil remains are as useful to geologists in determining the date of the rocks they are found in

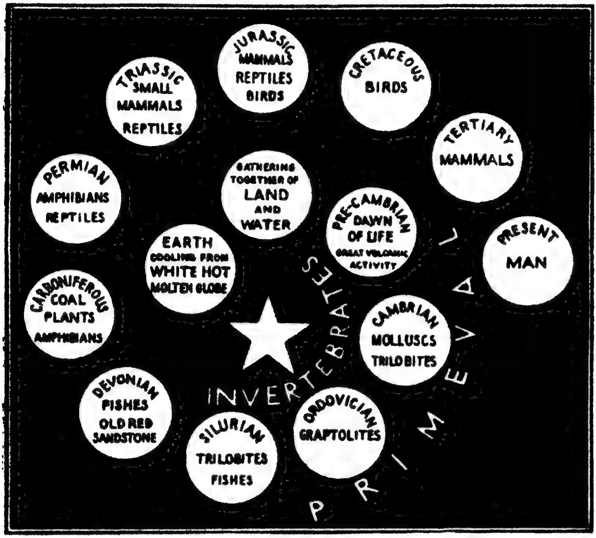


FIG. 83. CHART OF THE STAGES IN THE EVOLUTION OF LIFE ON THE EARTH FROM A STAR TO THE HOME OF MAN

as old coins are to the archæologists. We know the period of the world's history during which these animals existed, and can therefore say that if a certain unknown rock contains their fossils it must have been formed during that period.

Geologists have now fitted all the rocks into their places, and determined the order of their creation, in

much the same way that you can piece together the different pieces of a set of picture-puzzle blocks so as to make up the complete picture. There are still a great many blanks to be filled in, and a great many theories to be verified, before all the worlds that have existed before this one are scientifically reconstructed.

The conditions of life at different periods in the world's history were so varied as to constitute almost a different world. If we could skin the earth like an onion, and lay aside all the different layers of rock, we could consider them as separate worlds, just as we separated the nest of Chinese baskets and laid them on the table.

The material of which the world was made was originally shot out from the sun, and has passed through many stages of cooling, from a gaseous state to a white-hot globe, when it appeared as an intensely bright star, and finally became a dead planet. Millions of years after this it became cool enough to allow the water vapour to condense and form a sea covering its surface.

The earliest traces of life found in the rocks are those of sea-animals. As we work our way upward through the long series of the sedimentary rocks we find the remains of the creatures which lived at the various stages in the world's history. Some of the Pre-Cambrian rocks contain traces of 'worm burrows.' The Cambrian rocks contain the fossil shells of primitive molluscs and a number of trilobites. In the slaty Ordovician rocks there are a number of markings which look as though they had been made by a lead pencil, but have been proved to be the fossil remains of primitive animals now

known as graptolites. The Silurian rocks contain a great variety of trilobites, some of which are two feet in length, and here we also find the ancestors of the fishes which became so numerous in the succeeding Old Red Sandstone or Devonian Age.

The rocks of the Carboniferous Period show a tremendous development of plant life, which forms the coal beds; and in this age the amphibious animals first make their appearance.

During the Permian or New Red Sandstone Period the amphibians attained to great size and numbers, and some of them became distinctly reptiles. During the Triassic Age the reptiles greatly increased, and true mammals made their first appearance. The rocks of the Jurassic Period show that huge reptiles must have swarmed over the earth, and some of them had learnt to fly, and were being gradually transformed into birds. The mammals are becoming more numerous and better developed. The Cretaceous or Chalk Age shows a great development in bird life. The Tertiary Period is by far the most important, for in its rocks we trace the rise of animal life to its highest development in man.

The history of Life, the tiny speck of living jelly which appeared when the Spirit of the Lord moved on the face of the waters, and, by a process of evolution extending over millions of years, developed into the human animal, with body, brain, and reason, is the most fascinating story ever written, but it requires a book for itself.

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